TRABALHO DE PROJETO

Mestrado em Engenharia Informática - Computação Móvel

Web-based Sports Scoring System for Trampoline Gymnastics Competitions

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Leiria, Junho de 2023

MASTER PROJECT

Computer Engineering - Mobile Computing

Web-based Sports Scoring System for Trampoline Gymnastics Competitions

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Leiria, June 2023

Acknowledgments

I want to express my deepest gratitude to my supervisors, who have guided me throughout this academic journey. Their expertise and support have been crucial in helping me achieve my full potential and complete this master's project. On every request from my side, there they were, supportive and enlightening, always ready to make me strive.

I also would like to acknowledge the hosting conditions provided by Instituto de Telecomunicações - Delegação de Leiria and the support of Trampolins Clube de Leiria, namely the coach Rui Branco for his valuable help in defining the requirements and testing all the functionalities during the implementation stage; he and the whole staff were always open, allowed and accepted suggestions. Thus, they have enriched my academic experience by stimulating intellectual growth and a collaborative environment, which was very fruitful for everyone - what a fantastic experience.

To my friends, family, parents, and wife who have played an indispensable role in my success, offering endless love, understanding, and encouragement. Their consistent belief in my abilities and tireless support has been the bedrock of my achievements. I am profoundly grateful to all those who have been a part of my academic journey, and I dedicate this accomplishment to each and every one of them.

Abstract

This work arises within the context of the Master's Project in Computer Engineering - Mobile Computing course, at Escola Superior de Tecnologia e Gestão do Instituto Politécnico de Leiria. The aim of this work is to describe the work carried out over several months, in partnership with the Trampolins Clube de Leiria. This is a local club, and as such, with somewhat limited resources, such as the competitions they manage and organize their judging solution were in need of improvements in terms of organization, speed, data acquisition, trust in the data, and resilience.

This work begins by presenting the methodology used, followed by a contextualization of the sport, and a brief presentation of some software available in the market. Next, a comparison between the various current technological solutions is presented, as a means of gathering the necessary information to make informed decisions for the presentation of a solution. There is also a chapter with the details of the proposed solution, a description of the technologies used, and the implementation details. Finally, various execution scenarios, tests, and questionnaires are analyzed, concluding with the project's findings.

The main goal of the project was to propose an architecture for a solution to be made available in trampoline competitions, in order to minimize manual processes and perform calculations automatically, thus reducing human error and accelerating the entire end-to-end process. There was also the objective of, during the development of the proposed solution, having it tested in actual events, including regional, national, and international competitions.

The project was successfully completed, with the club's main goals achieved. The experience gained in the interactions of requirement gathering was enriching for everyone. In the real-life context, the application's performance and output were accepted in all possible categories.

Keywords: scoring, trampolines, web application, cloud, on-premises

Resumo

Este trabalho surge no âmbito da unidade curricular de Projeto de Mestrado em Engenharia Informática – Computação Móvel, pela Escola Superior de Tecnologia e Gestão do Instituto Politécnico de Leiria. O objetivo do mesmo é descrever o trabalho realizado durante vários meses, em parceria com o Trampolins Clube de Leiria. Este é um clube local, e como tal de recursos algo limitados, pelo que a gestão das provas que organizam e sua solução de ajuizamento estava necessitada de melhorias ao nível da organização, rapidez, aquisição de dados, confiança nos mesmo, e resiliência.

Este trabalho começa por apresentar a metodologia utilizada, e de seguida é efetuado um enquadramento do desporto, assim como uma breve apresentação de alguns dos softwares disponíveis no mercado. A seguir, uma comparação entre as diversas soluções tecnológicas atuais, como forma de recolher a informação necessária de modo a tomar decisões informadas para a apresentação de uma solução. Existe ainda um capítulo com o detalhe da solução proposta, bem como a descrição das tecnologias utilizadas e os detalhes da implementação. Por fim, são analisados os vários cenários de execução, testes e questionários realizados, terminando com as conclusões do projeto.

O principal objetivo do projeto foi propor uma arquitetura de uma solução a administrar em competições de trampolins, para que se minimize os processos manuais e que os cálculos sejam realizados de forma automática, para assim reduzir erro humano e acelerar todo o processo de ponta a ponta. Foi também definido o objetivo de, após o desenvolvimento da solução proposta, a aplicação ser testada em eventos reais, incluindo provas regionais, nacionais e internacionais.

O projeto foi concluído com sucesso, sendo que os principais requisitos indicados pelo clube foram desenvolvidos. As experiências adquiridas nas interações de levantamentos de requisitos foram enriquecedoras para todos. No contexto real, a prestação da aplicação foi aceite em todas as categorias possíveis.

Palavras-chave: ajuizamento, trampolins, aplicação web, cloud, on-premises

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List of Acronyms and Abbreviations

CRUD - Create, Read, Update and Delete

CSS - Cascading Style Sheets

DOM - Document Object Model

ESTG - Escola Superior de Tecnologia e Gestão

FGP - Federação de Ginástica de Portugal

FIG - Fédération Internationale de Gymnastique

HD - Horizontal Displacement

HTML - HyperText Markup Language

IPL - Instituto Politécnicao de Leiria

JS - JavaScript

LAN - Local Area Network

MQTT - Message Queuing Telemetry Transport

MVC - Model-View-Controller

OS - Operation System

PHP - Hypertext Preprocessor

RAD - Rapid Application Development

SDK - Software Development Kit

TCL - Trampolins Clube de Leiria

TCP/IP - Transmission Control Protocol/Internet Protocol

ToF - Time of Flight

UX - User experience

UI - User Interface

VM - Virtual Machine

Chapter 1

Introduction

Technology information systems have played a fundamental role in the evolving world of sports and are growing rapidly. In football, for instance, new devices are used for different reasons, such as to help referees in decision-making or quantify the athletes' performance during a game, thus assisting coaches in setting the training program and the game strategy. One of football's most famous and recent technology is "goal-line technology." It determines if a ball has crossed the goal line to support the referee's decision [1]. Previously, the world saw much more coming, such as chronometers, sprint running, automotive sports, and photo finish, as a way to tie-breaking.

Currently, sports are gaining more and more advantages from adopting technology. Scoring decision sports, which generally have a panel of judges, grading an athlete's (or team's) performance are among them. Such sports include gymnastics, dive jumping, figure skating, and synchronized swimming. Judges' scores are combined, and the final result determines the competition's winner. Each sport governing body is responsible for setting and enforcing quality control parameters for judging performance. Such rules and parameters are to be followed by the panel of judges, whose scores are commonly combined with mathematical equations to produce each athlete's evaluation [2].

Focusing on the scenario we will use in this work, the panel of judges assesses a particular routine in trampoline gymnastics. They do this based on evaluating the overall degree of difficulty, overall skill execution, and, depending on the trampoline discipline, the time of flight (ToF) duration, i.e., the actual amount of time an athlete is on the air [3]. Trampoline gymnastics scoring is where information systems may shine and make the scoring system more agile, effective, and proficient. The result of scoring input, ranking, and making all these information output benefits greatly. These benefits can be on a pre-process, during, and after the event and can target athletes, coaches, the audience, and the public in general.

1.1   Context and goals

The context of this work emerged from a local Leiria club, Trampolins Clube de Leiria (TCL). This small and young club was challenged when organizing local and national trampoline competitions. In this work, we propose developing an information system to cover the process of organizing the entire length of an event. It starts with athletes' and clubs' enrollments, then supporting the judging, and presenting final scores. Such support assures the natural flow of the competition, allowing timely scoring and presenting relevant information to all involved. The logo of the club is shown in Figure 1.1.

Figure 1.1: Logo of: Trampolins Clube de Leiria'

Trampoline gymnastics is a competitive Olympic sport with a wide range of regional clubs hosting local events. These small-dimension clubs host events following the same complex domain logic: Recreational, local, or regional. Developing an information system within these organizations is usually out of budget, and other solutions may arise as alternatives. Manual paper systems are cumbersome, and spreadsheets and documents take over. Such endeavor tends to be very complex, which may translate to a final valuable information system. However, such solutions are inadequate and do not usually support all necessary features like a proper information system modeled to the practice.

As information systems may simplify calculating scores, such workflow has to start earlier from an event's point of view. Application or subscription has to happen, with detailed information needed to provide the echelons and disciplines involved. Therefore, an event leveraged by an information system may have the technology leap starting at enrollment, instantly processing the event workflow. There are many data to be managed that are cumbersome to be process manually.

TCL was facing these challenges, and the partnership with Escola Superior de Tecnologia e Gestão (ESTG) from Instituto Politécnico de Leiria (IPL) could take place to assist the club in tackling all its difficulties by providing a solution with information systems.

The main goals for this work include the following:

- Review of the state of the art of sports scoring systems with a specific focus on trampoline gymnastics, analyzing the different disciplines

- Review of the state of the art of current technological solutions for sports scoring that can support the desired functionalities

- Propose an architecture for a scoring system for trampoline competitions

- Design and implement the proposed architecture

- To carry out tests in real scenarios, with real trampoline competitions, and collect feedback from hosts, judges, trainers, and athletes.

Such a solution has many processes to be modeled to minimize manual configuration and inputs to host an event. As previously stated, if such a solution starts its handling by registering the event data and modalities taking place, it is a good starting point to maximize its utility and performance. In a trampoline competition, an enrollment may define a mixed setting of modalities and teams, producing a defined number of routines to evaluate. Evaluated routines lead to rankings grouped by modality, echelon, and gender. After performing each routine, the scores assess rankings. They are essential information for athletes, coaches, and the audience. The routines also have to follow a specific order based on echelons.

All these domains will be covered with greater depth later, but entering briefly on such complexity of processes allows us to assess some of the complexity the system should tackle.

1.2 Methodology

For a complete solution, the development must include assessing the requirements with club managers and coaches from end to end. It means it has to cover from enrollments to the final result of obtaining rankings and their broadcast.

While the ideal approach was agile scrum planning, the scope is vast (given the team size) and controlled by hard limited dates of the events/competitions. The software team comprises four elements: three project managers and one developer. This team can only rely on one person from the club to provide insights, business rules, acceptance tests, approve feature developments, and bug fixes. Therefore, reasoning about the scope to include in sprints and building up domain rules in user stories was impossible to fit. Even so, modeling, implementing, and testing was still very iterative (vs. linear waterfall) [4]. Every requirement was registered in a paper, spreadsheet, or handed over in a digital format and readily implemented as a software feature.

It was not ideal, but we made it work successfully, sometimes relying on late-night calls, verbal explanations, quick hotfixes, and waiting for feedback. So this was a functional

form of incrementing functionalities, finding (and fixing) bugs, deciding which features to do next, prioritizing some, and sacrificing others.

This risk management also puts aside "perfect features", favoring the optimal and possible ones given the team size, communication bandwidth, and time constraints. We decided that registering such "perfect features" and producing a backlog for future work is not to do. It would compromise the readiness for the scheduled events throughout the year.

There were a series of meetings and delivery of sprints, parts, and functional software pieces so that progressive feedback could support the next iteration. There was mainstream back-and-forth information from the club end with a team coach with a broad perspective and experience in the complete workflow. Also with assistant club managers, other coaches, staff, and judges.

From early on, every release and implemented feature is put online on a cloud server so TCL club members can try it remotely, approve and provide feedback. This is the fastest model of iteration we can implement, where all installations and updates don't need any user interaction. We must consider the ease of update and maintenance on the "on-premises" version (which initially runs on a Virtual Machine). These tasks must be readily available on demand by the user.

The real-world scenarios were competition events in Leiria - twice on 2018-05-05 and 2019-05-04, Coimbra on 2019-03-09, and Cascais from 2019-04-12 to 2019-04-14. These were, respectively, local, regional (Figure 1.2), and international (Figure 1.3) range competitions. The implementation details are put to the test, end to end, with organizations, judges' boards, coaches, athletes, and the audience. We conducted surveys to gather as much feedback as possible, which was optimistic and likely to guide us in enhancing features.

Figure 1.3: Athletes' screen at an International Event, Cascais Beach Cup 2019

Figure 1.2: Athletes' screen at a National Event, Coimbra 2019

1.3 Document structure

After this introductory chapter, Chapter 2 presents a review of current sports scoring systems, focusing on trampoline gymnastics that is detailed and analyzes the different disciplines.

Chapter 3 includes a review state of the art of current technological solutions for sports scoring that can support the desired functionalities, including server-side and client-side solutions, free and paid solutions, and concluding on the advantages and disadvantages.

The proposed solution is detailed in Chapter 4, including a distributed architecture that supports a data model and the future implementation of the solution.

Chapter 5 presents and details a system implementation that meets all the requirements and functionalities, considering the processes workflow and detailing the choices made regarding user experience, customization, and flexibility to cope with the exceptions that may (and will by experience) arise. Chapter 5 also includes testing of the solution, analysis of the compliance with the functional and non-functional requirements, behavior during partial tests with the club, and the users' experience during actual live events.

Finally, 6 presents conclusions and possible lines of future work.

Chapter 2

Sports scoring systems

This chapter will cover the concepts necessary for the implementation of the project. First, a brief introduction to scoring systems in sports will be given, followed by a brief presentation on trampoline gymnastics. Then, the current solutions for recording scores will be presented, ending with the challenges of evaluating trampoline gymnastics.

Sports date back to Ancient History and have since been evolving, constituting the subject of several research studies [5, 6], also supported by the European Committee for the History of Sports [7]. The Modern Olympic Games started in 1896, with an estimated crowd of over 60,000 attendees, introducing the first marathon and covering sports such as athletics (track and field), cycling, swimming, gymnastics, weightlifting, and more [8].

While there are many ways to assess the ranking in a given sport, we will focus on the ones with a judging panel, e.g., gymnastics, dive jumping, and figure skating.

In the following, we introduce the main challenges in sports scoring systems and then focus on trampoline gymnastics, detailing the judging workflow. We will also present the current approaches, comparing their potential.

2.1 Introduction to sports scoring systems

In any given sport, if a scoring mechanism is not in place, it would make it just recreational, to begin with. Not that such thing would be a problem, but as in human nature, the desire to grow, evolve, and achieve more and more comes to a best match with the competitive side of sports. It's how an athlete may assess (or monitor/measure) its evolution and its reference (position). That's how to set a prestige mark, records, and limits to beat. That's the drive for the athletes, making them wake up early and have two or more practice sessions daily. That keeps the momentum needed to follow strict diets and sacrifice personal (of what could be) leisure time devoted to pursuing more.

As the Olympic motto goes, *"Citius, Altius, Fortius"* ("Higher, Faster, Stronger"). The best possible outcome is met when all these elements are a realization of a healthy, fair environment for all participants [9, 8].

Scoring mechanisms may vary considerably, given the differences in the objectiveness of a sport. For instance, swimming or high jump, where the score's main quota is measurable by a chronometer or a ruler, and for example (more subjective), judo or gymnastics. In contrast, the performance is obtained from a judge or panel of judges that following some rules, will always end up with an opinionated perspective, or to say the least, its perception of the athlete's performance. Notably, this is a key point that every judge must have their certification or education in place to ensure consistency [10].

There are many challenges faced when it comes to sports scoring systems. At first glance, the scoring system must ensure that the set of rules for the event is up to date. They will likely change with every World Championship, Olympic cycle, or event organization in smaller-scale events. This potential lack of standardization directly affects the system and the people interacting with it. If domain rules change, interacting people should be aware, and the system ideally presents an intuitive process or set of steps to conclude a specific task [11]. As previously noted, the judge's personal opinions may influence the scores, thus introducing another challenge: the judge's training and, of course, finding qualified judges with experience consistent with fairness and accuracy.

With such subjectivity involved, it's only natural to expect protests to arise. Athletes, coaches, and spectators will eventually disagree with the scores. Thus, there must be transparency and clarity in the scoring system. Specially when the complexity of scoring is high, it must be clear to everyone.

Multiple factors are somewhat subjective, such as difficulty, execution, form, and creativity. Such traits on the scoring system will certainly diminish but not mitigate all disagreements, so disputes must have a clear process to be filed, managed, and resolved.

Not to forget, judges are humans, and like any, even the most experienced can make mistakes or suffer from environmental interferences, such as noise or similar.

While there are somewhat subjective terms in scoring, some are quantifiable and measurable. For instance: displacement and timings. This means some scoring systems may rely on technology such as sensors, cameras, and software (artificial intelligence) to obtain measurable data. These come at a price point that may not be affordable to everyone, especially small-sized organizations or clubs.

User experience (UX) is also a significant challenge. Currently, in this era of digital consumers, people have become very demanding, even if they don't realize it. This is a product of the fierce competition between enterprises, social networks, content platforms, and many more, which will benefit if the user has a better experience with their prod-

ucts. To achieve this, speed, handy interaction elements, information accuracy, content prediction, good-looking assets, and high-resolution pictures are "big guns in this war" [12]. Everyone that interacts with the scoring system has a user experience.

Directly related to the UX is the User Interface (UI) design. For example, text inputs should have the space to "breathe" to optimize readability. Primary actions buttons should benefit choices of solid backgrounds over secondary actions, which should benefit outline choices. As a rule of thumb, the red color is for "danger", a destructive operation that cannot be undone [13].

Having an online output on a platform or website is also an excellent challenge, as it will empower accessibility. Therefore, fairness by monitoring and normalization of scoring will have better conditions to flourish. This also addresses the purpose of statistics, achievements, and records, which is also challenging. Hardly it is a good job of inputting data for publishing manually, so if this could be part of the scoring mechanism, this process would be better and more seamless.

Another good challenge for the scoring system is how versatile it can be to rank different modalities by configuration. For example, artistic, rhythmic, and trampoline gymnastics have some variations but can be grouped in the same scoring system. They have the exact ideological nature, having to score a given number of performances in an event. Mark input names, dataset ranges, and formula calculations will vary, but in a controlled way, may be scored by a system that knows how to handle them, with the proper ways to have the configuration of the event.

These challenges show how sports scoring systems present numerous opportunities for enhancement that are still evolving for most sports.

2.2 Trampoline gymnastics

In trampoline gymnastics, athletes use trampoline devices to catapult themselves in jumps through the air that can surpass six meters without any technological device strapped to the body. Being so launched in the air is a common situation, where they almost look like flying, sometimes risking too much, leading to loss of control and uncontrolled falls, leading to a bad score, or worse, physical injuries. To minimize such, the trampoline devices are mounted with side cushions all around and with coaches holding extra cushions, throwing them to the zone where they predict to hit [14].

The first trampoline was created in the early 1930s by George Nissen and Larry Griswold. Soon after that, in 1947 and 1954, the first unofficial and official American championship happened and has continued to flourish ever since. It's been an Olympic modality since 2000 [15]. A world championship occurs every year, except for the ones with the

Olympic games. The series, before that, serves as an important Olympic qualifier. Other major events are:

- World Cup, with Individual and Synchronised Trampoline events (Tumbling and Double Mini-trampoline competitions are optional)

- The World Games, with Synchronised, Tumbling, and Double Mini-trampoline events

There are four categories or disciplines:

- Individual Trampoline, where ten skills are performed in sequence without stopping to hit all elements in the trampoline center. Athletes perform two routines: special requirements at first, with a focus on execution and time of flight, followed by a voluntary one, focusing on difficulty, execution, and time of flight. The performance scoring is judged on difficulty, execution, and ToF. Deductions occur on traveling (horizontal displacement (HD)), form breaks, bouncing out, and lack of control in ending routine [14, 16] (See figure 2.1);

- Synchronised Trampoline, use the same device, but twice, one for each athlete that forms the competing pair. Athletes perform the same exercise lined up side by side. They also perform ten skills in sequence without stops, aiming to hit all elements in the trampoline center. However, adding to all previous rigors of maintaining perfect control of skill sets, they must stay in perfect sync, mirroring the partner's movements as close as possible. They must perform the same elements at the same time and must start facing the same direction. However, the twisting movements are not required to be in the same direction [14]. The sequence is almost identical to an individual trampoline, with a special requirements routine - also focusing on execution, HD, and now, synchronization - and a voluntary routine - also focusing on difficulty, HD, execution, and of course, synchronization. Hence, additional deductions occur when the pair doesn't perform the same skill or falls out of sync [16] (See figure 2.1)

- Double Mini-trampoline, this modality involves a gymnast performing two separate routines on two smaller trampolines in succession. The first routine is performed on the first trampoline, but the landing happens on the next one, the main trampoline. Gymnasts are judged on the execution, form, and difficulty of their routines.[14] (See figure 2.2).

- Tumbling, this modality involves a gymnast performing a routine of acrobatic maneuvers on a spring runway without using a trampoline. Gymnasts are judged on the execution, form, and difficulty of their routines.[14] (See figure 2.2).
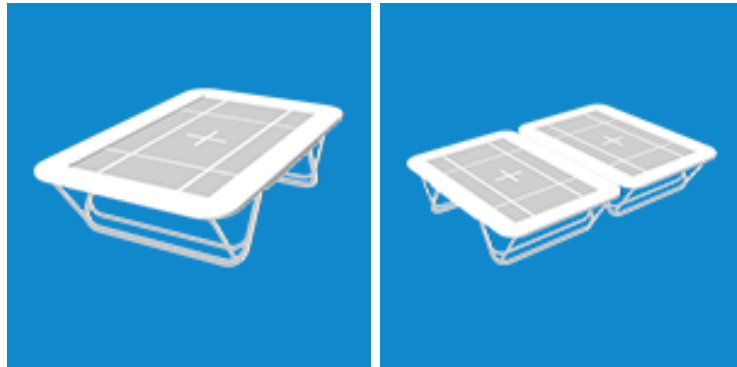
Figure 2.1: Image of individual trampoline (left) and synchronized trampoline (right)
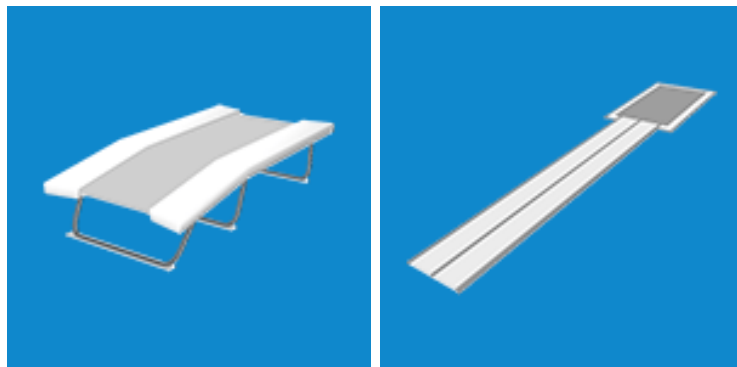
Figure 2.2: Image of the double mini trampoline (left) and tumbling (right)

2.2.1   Scoring in trampoline gymnastics

Scoring in trampoline gymnastics is based on two main components: difficulty and execution. The difficulty score reflects the complexity of the routine, and the execution score reflects how well the athlete performs the routine. Electronic scoring systems can automate the scoring process and reduce the potential for human error. They display the final scores for the athletes and the audience to see. Scoring in trampoline gymnastics requires expertise, experience, and attention to detail to ensure fair and accurate results.

Generally speaking, there are four evaluating categories that contributr to the final score [17, 16]:

- Difficulty (D);

- Point Execution (E);

- Time of Flight (ToF);

- Horizontal Displacement (HD);

- Synchronisation (S);

The difficulty score is determined based on the elements included in the routine. Each element is assigned a predetermined difficulty value, and the difficulty score is calculated by adding up the difficulty values of all the elements in the routine. Two judges observe the difficulty of the routine, where each jump is evaluated according to the Point Code (provided by the Federation Internationale de Gymnastique (FIG)).

Judges evaluate the athlete's form and landing for Point Execution. Form refers to their body position and technique during the routine, including their body alignment and posture, height, and control of the jumps. Landing refers to how well the athlete lands and finishes the routine, including the position of their feet and how they absorb the impact. Systems that do have sensors also carry out Horizontal Displacement measurement, which is based on the place where the athlete lands on every contact. The score starts at ten (10) and is deducted each time the gymnast misses the center of the trampoline. Another measurement made by sensors is the time of Flight (ToF), which registers the time the athlete is in the air, excluding the time he/she is in contact with the trampoline. Synchronisation (S) is evaluated in the case of synchronized trampolines, it is a measurement performed by sensors, and there is a penalty if the athletes are out of sync. All small-sized clubs don't have the budget for such equipment, so such tasks are carried out by the judge panel.

Each judge evaluates the routine and assigns a score based on their assessment of the athlete's performance. The scores are then averaged to determine the athlete's final execution score.

Once the difficulty and execution scores are calculated, they are added to determine the athlete's total score. The highest and lowest execution scores are dropped, and the remaining scores are averaged to determine the final execution score. The ToF and Penalties are then added to determine the athlete's total score. The athlete with the highest total score is the winner of the event.

The final calculation of the complete routine for individual trampolines consists of adding all the areas and subtracting the penalties. On the synchronized trampoline, also occurs evaluation of synchronization.

$$FinalScoreIndividual = D + E + ToF + HD - Penalty \qquad (2.1)$$

$$FinalScoreSynchronised = D + E + ToF + HD + S - Penalty \qquad (2.2)$$

As previously mentioned, the trampoline competitions have two routines of 10 elements each. The first routine has mandatory jumps and is relatively simple, with four of them (at the athlete's choice) that are evaluated in the area of difficulty and cannot be repeated in

the second round of qualifying. The second routine is considered voluntary, the athlete's responsibility; all the jumps are evaluated in difficulty and execution. The sum of the two routines defines the athletes that go on to the final [17, 16].

2.2.2   Trampoline gymnastics competition process

Before starting the events and the process of evaluation of the athletes, there is the organization of the event. Every event that is part of a championship is the responsibility of the Portuguese Gymnastics Federation (FGP), in conjunction with the clubs that will host the event [18].

Typically, any event starts with planning and promotion. In small-sized clubs' reality, choosing the venue and date is common to be at the training facilities or a nearby location with the capacity to receive a public audience. Of course, this varies if it's a local, national, or international grade event. Not only a venue, but there's also the need to set up everything, trampolines, mats, and all sorts of stuff related to this day. The panel of judges has to be appointed and ensure they have everything they need to do their job adequately. The event has to be promoted to attract spectators and generate interest in trampoline gymnastics which in small-sized clubs is typically in their network of other clubs, athletes' friends, families, and so on. The logistics of transport, accommodation, food, water, and healthcare depend heavily on the scope of the competition.

Finally, so that all this can occur, athletes must register for the event, and all necessary information must be provided so that all competitions of the event comply with the rules. Athletes choose modalities(s) they want to participate in, may form teams, and will fit into a category or echelon. The following figure shows a table, taken from the general and competition regulations of the FGP, where the scales/categories for all the sports under its responsibility are defined; for this work, the ones in column TRA [18].

Within each modality (or discipline) and echelon, the order of passage of the preliminary competition is determined by lottery. In contrast, in the final competition, the athletes are ordered by order of merit of the preliminary competition, starting with the athlete with the lowest score.

2.3   Challenges in trampoline gymnastics judging

Accordingly to the previously stated, the biggest and broadest is justice or fairness, having equality across the sport's universe. Such would mean normalizing scores, from one event to another, from one panel of judges to another, across countries, measurement equipment, etc. This score normalization may give an opportunity for complaints to arise, and that

Escalão / Categoria	ACRO		AER	GAF	GAM	TRA	GR	TG
	Base	1ª Div.						
Benjamins			6 anos	6-7 anos	6-8 anos	6-8 anos	6 anos	
Infantis	7-13 anos		7-8 anos	8-9 anos	9-10 anos	9-10 anos	7-9 anos	
Iniciados	8-15 anos		9-11 anos	10-11 anos	11-12 anos	10-12 anos	9-10 anos	
Juvenis	9-16 anos	11-16 anos	12-14 anos	12-13 anos	13-15 anos	13-14 anos	11-12 anos	10-14 anos
Juniores	10-18 anos	12-19* anos	15-17 anos	14-15 anos	16-18 anos	15-16 anos	13-15 anos	13-17 anos
Seniores	>= 12 anos	>= 12 anos	>= 18 anos	>=16 anos	>=18 anos	>=17 anos	>= 16 anos	>=16
Elite *Juniores*	As mesmas idades dos escalões de Juniores e Seniores. Acesso dependente de patamares técnicos especificados nos manuais respetivos. O acesso às categorias elite é sempre nominal.				14-18 anos	13-16 anos	As mesmas idades dos escalões de Juniores e Seniores. Acesso dependente de patamares técnicos especificados nos manuais respetivos. O acesso às categorias elite é sempre nominal.	
Elite *Seniores*					>=18 anos	>= 17 anos		

* Diferença de idades máxima = 6 anos, 7 para os grupos masculinos

ACRO - Ginástica Acrobática   AER - Ginástica Aeróbica   GAF - Ginástica Artística Feminina
GAM - Ginástica Artística Masculina   GR - Ginástica Rítmica   TRA - Ginástica de Trampolins
TG - TeamGym

Figure 2.3: Echelons defined by FGP [18]

is reasonable because when we are dealing with performances, the slightest difference in a mark may set the difference between making it to the podium or not for the same athlete's performance. Challenges of technical nature may also occur, so having the equipment well calibrated, is necessary to ensure that they assess the correct value, say for the ToF - i.e., the actual amount of time an athlete is on the air.

Returning to the UX and thinking on the users, starting from the event owner, that has the role of inputting all the data necessary to start the event, to the simplest form, to a visitor that will "only" look for results. For example, a coach will have a better UX if he/she has direct access to their athletes' relevant information. If a judge can insert a set of marks with, say, 20 keystrokes and have the next jumper ready to choose with a click, it will be a much smoother and enjoyable experience than if he would have to be browsing through panes and clicking of changing the input manually.

Another related challenge is the scoring of judges' performance. For fairness' sake, and ideally, a given athlete's performance would be equally scored across environments (as previously stated, by event, country, the panel of judges, and so on). A scoring system may play a massive role in this assessment. Having the event's history, detailed marks, and a video recording of the performance, a sub-system (or parallel) could take place to assess whether any given performance scoring was "by the book". It could serve as a reference, feedback, and complaint but also as part of the judges' educational programs.

2.4   Conclusion

In this chapter, we have presented scoring systems in sports focusing on trampoline gymnastics and describing the main features and the significant challenges and requirements

that must be addressed. It was shown that, so far, there is no known solution accessible to small and medium-sized clubs so that they can organize trampoline events efficiently and effectively.

There are many challenges, the organization is complex, and the calculations are time-consuming. The clubs have to guarantee all the necessary material for the event to run correctly, and the panel of judges has to have the correct access to evaluate the athletes in the best possible way. The whole issue of logistics, with the need to acquire software to format all the information and configuration of the event, ends up being too expensive (both financially and in terms of useful time) for small and medium-sized clubs, as is the case of TCL.

Thus, there is an opportunity to create a technological solution scaled to the problem. This work focuses on the modalities of the individual trampoline, synchronized trampoline, and double mini-trampoline because they are practiced in TCL.

Chapter 3

Technological solutions

For now, there are severed opportunities to solve this challenge, but there is no "one size fits all" solution, so a few requirements and customization preferences will help decide the best fit. In this chapter, we will present the current solutions for trampoline scoring and the most obvious (closest to optimal) solutions and compare them, taking a step toward the implementation.

3.1 Current solutions for trampoline scoring

As previously mentioned, several solutions are on the market for managing events and recording the scores of athletes during them. Still, they may not be within reach of small and medium-sized clubs. A quick search allows us to verify that most require an annual or monthly fee and that multiple licenses may be necessary to work with it, resulting in a relatively large sum of money. Considering the increasing demand to computerize all information and reduce the volume of paper printouts, software within reach of smaller clubs, distributed at scale, is an advantage. For example, Sport Tech is a software that provides a platform to record and calculate the scores, as well as the possibility of providing information to the public in real-time, not being clear about the integration with devices for ToF or HD detection. However, the software has a cost per athlete or per direct contract with the company responsible [19]. Another example would be TScore, a transversal software for several disciplines besides trampoline gymnastics, such as artistic gymnastics or gymnastics acrobatics. It also allows the configuration of the tests, the registration of scores, and the calculation of the classifications. It also mentioned the possibility of integration with ToF systems. However, the licenses are purchased for each computer used. It has a duration of one or three years [20].

Since these costs are difficult for smaller clubs to bear, it was logical to start evaluating the possibilities of developing a software program that would meet the needs of TCL and

help the club to manage its registrations and competitions.

3.2   Possibilities

As technology progresses, the power of technology increases, the cost also reduces and the
efficiency increases, thus more resilient solutions become accessible. Thus, the conditions
become more conducive to creating a custom application, allowing an adequate choice
of infrastructure that meets the application's requirements. Several types of software
platforms can be utilized to build such an application. This chapter explores the various
categories of software platforms available, including native desktop, web, mobile, hybrid,
and cloud-based applications. By understanding the advantages and disadvantages of each
platform type, we can design and develop a custom application that meets the specific
needs of the trampoline gymnastics event.

3.2.1   Software Platforms

Trampoline gymnastics competitions require a complex system to manage athlete reg-
istration, event scheduling, score calculation, and results display. To meet these needs,
various software platforms can be used to support the entire competition process. In this
chapter, we will explore different types of software platforms that can be used to build
a custom application for managing a trampoline gymnastics event. Specifically, we will
discuss native desktop applications, web applications, mobile applications, hybrid appli-
cations, and cloud-based applications. By understanding the features and benefits of each
type of software platform, we can better design and develop an application that meets
the unique needs of trampoline gymnastics clubs and organizations.

1. Native desktop applications: These are applications that are built for a specific
   desktop operating system, such as Windows, MacOS, or Linux. Native desktop
   applications can provide high performance and access to device-specific features but
   require separate development efforts for each platform.

2. Web applications: These run in a web browser and can be accessed from any device
   with an internet connection. Web applications are easy to access and can provide
   a consistent user experience across platforms but may have limitations in terms of
   performance and features.

3. Mobile applications: These are designed specifically for mobile devices, such as
   smartphones and tablets. Mobile applications can provide a great user experience

and access to device-specific features but may require separate development efforts for different platforms.

4. Hybrid applications: These applications combine elements of native and web applications. Hybrid applications can provide a great user experience and access to device-specific features while leveraging web-based development's benefits.

5. Cloud-based applications: These are hosted in the cloud and can be accessed from any device with an internet connection. Cloud-based applications can provide scalability, flexibility, and cost savings but may require additional security and performance considerations.

The first decision is to understand which approach to consider: will it be an application for native or will it be a web application?

A web application is an application that runs on a server and is available via access via a web browser program [21], while a native application is an application built for a specific operating system (OS) on a specific development platform. A hybrid application will be an application that brings together the advantages and disadvantages of a web application with a native application [22].

With the evolution of web pages, there has been an increasing trend to port native desktop applications to the web, creating advantages over desktop applications. A web application has the advantages of [22]

- run in a browser, not being dependent on a specific OS as with desktops;

- does not need a Virtual Private Network (VPN) to access since HTTP or HTTPS carries out access. If it were necessary to have information centralized in a server, the desktop would have to be in the same network as the server or have a VPN to be able to access it;

- It is accessible from anywhere in the world through an internet connection. The desktop application is always available, regardless of whether there is an internet connection.

However, the last point is also the big disadvantage of web applications: without an internet connection, which may not be guaranteed everywhere, it is not possible to access it, limiting the user's use. A native application will only be accessible through the distributor's platform (Apple, Android, Windows) and is installed on the device. However, there are advantages such as [22]:

- the application is developed for a given platform and with the platform's environment exclusively in mind;

- the application is accessible without an internet connection, provided there is no need to log in or access external data, as all data is stored on the device.

However, the fact that it is necessary to deploy an application for each OS and perform maintenance on all of them, turns out to be a disadvantage of this type of application if you want to be present in all markets [22].

3.2.2   Software on-premises vs. cloud

Another point that needs to be assessed is the type of application hosting: is it on-premises or in the cloud?

Software on-premises is when the infrastructure exists all on site, including the server where the software is installed, and the computers, which have the software installed, communicate with that server. Cloud software, on the other hand, means that the software is hosted on a contracted service and there is no need to guarantee the infrastructure on-site, only an internet connection is required to access the resources/software [23].

There are several advantages to opting for a cloud service, these being [24, 25]:

- the reduced costs, as the entity that will use the software, does not need to buy the resources, and can rent them;

- The management of the infrastructure, is the responsibility of the entity from whom the service was acquired, the user only needs a device with an Internet connection;

- Scalability, as it is a contracted service, it is only necessary to increase or decrease the service in order to scale the software.

There is a need on the part of suppliers to ensure the security of systems so that their customers do not see their data threatened or lost.

Cloud computing consists of three types of modules [25]:

- Software as a Service (SaaS) consists of hiring the machine and user interface;

- Platform as a Service (PaaS), consists of the hiring of the platform and/or solutions;

- Infrastructure as a Service (IaaS), is the hiring of infrastructures, usually using a virtualized environment.

3.2.3   Distributed architecture applications

A distributed architecture consists of a set of processes running in parallel and exchanging messages between them, with each process holding a group of variables that another

process can change. Messages can be delivered synchronously, in which the receiver must accept the sender's message; or asynchronously, in which the sender always delivers its message, even if the receiver is unavailable [26].

In the Client-Server model, the client (in this case, the computer) sends a request to the server, which, after processing the information, replies to the client with the results obtained. In this model, it is the server that is responsible for recording and processing all the information, as well as returning it to the various clients. In the case of a web application, the client will be each browser that is communicating with the application [27].

In the Peer-to-Peer model, on the other hand, all clients are networked together and share resources. Each device is both a provider and a client. This network can have a central entity/server ("Hybrid" Peer-to-Peer) as well as only servants ("Pure" Peer-to-Peer) [28].

Figure 3.1 shows the representative schemas of a Client-Server architecture and a Peer-to-Peer architecture.
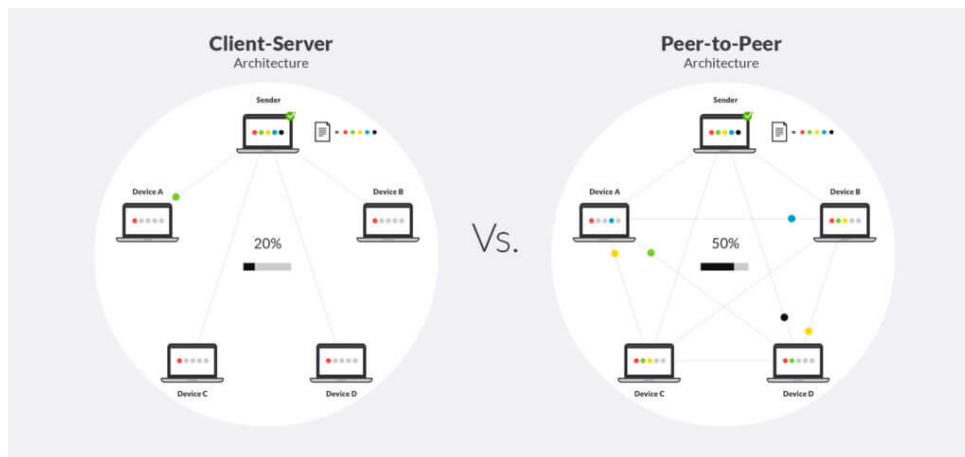

Figure 3.1: Distributed architecture schemes [29]

3.3   Comparative Analysis

A native solution reduces the complexity of logistics to almost non-existent but limits it to one (simultaneous) application user for a given moment. Once connected to the internet and once installed on a device, that device becomes the only piece needed for all the management of an event, with all the good and counter-parts it brings.

With no need for connectivity, it makes it easy to operate in any geographical conditions - whether there is fixed internet on-site or a good mobile network signal. The speed and robustness of communication between application areas are ensured. However, data

Table 3.1: Comparison between a native application and a web application

	Native	Web (client different from server)
Logistics	Nearly non-existent	Nearly non-existent
Internet connection	Does not require	Does not work without Internet or LAN connection to the server
Simultaneous users	Cannot	Multiple users
Security of data (loss, malfunction)	Cannot guarantee	Only if there is server failure
Data backup	Complex	Can be managed

security, in terms of theft, accident, and breakdown, is fragile; redundancy and backup are also very difficult since all the information is stored in a single device.

On the other hand, a web solution would also present a logistical complexity that is practically non-existent but would allow access to several users simultaneously. For that, its availability would have to be guaranteed through an internet connection or a Local Area Network (LAN), accessible to all devices with an internet or LAN connection through a browser (either a computer or a mobile device).

Part of the data security is guaranteed since the information is stored on an external device. Access to it is not guaranteed since the server may be on a different LAN or there may be no Internet connection.

Table 3.1 summarises the comparison made in the previous paragraphs for a native vs. web application.

Taking an example of a web application, if it is on-premise, it will present the exact logistics of installation as a native application. Everything has to be installed on one device to be accessible. It also has the disadvantage that the data is only on one device; if something happens to the device that cannot be accessed, the data is lost and cannot be accessed. However, even if everything is installed on a single device, other devices can view the web application if there is local connectivity.

If that same web application is in the cloud, it already allows all users to have access without having to install the application (reduces the complexity of installation), i.e., the application is installed and updated on the server (which can be hired as a service) and there is the guarantee that when the user connects, he or she is accessing the most updated version. Another advantage is that there is no need to install the application on the end user. All that is needed is a device - computer, tablet, or smartphone - or

Table 3.2: Comparison between an on-premise web application and a cloud web application

	On-premise	Cloud
Logistics	Same as a native application	Does not need to be installed on the client
Internet/network connection	Does not need	requires Internet connection
Simultaneous users	Possible, if connected on the same LAN	Can be done, provided the device has Internet access
Application updates	the latest version is not guaranteed (update must be performed on the device)	The same version is guaranteed for everyone (more accessible update process)
Data security (loss, malfunction)	cannot be guaranteed	Only if there is server failure
Data backup	Complex	Can be managed or contracted

similar, with a web browser installed. However, for this to be possible, there must be an internet connection at the place from where the user is trying to access (in this case, the test locations).

By choosing this type of architecture, it will be possible to implement a separate application module (or separate application entirely) accessible to athletes, coaches, judges, and the public. It will also be possible to provide a live results screen both for the equipment, the public (giant screen), and smart devices.

Table 3.2 summarises the comparison made in the previous paragraphs for an on-premise application vs. the cloud, considering the use of a web application.

If it is a client-server architecture for an on-premises application, there is the advantage that there is no need for internet connectivity; local connectivity is enough. However, this increases the complexity of the logistics and installation of the application and makes it more difficult to maintain updated and compatible versions. Since there is only one place where the information is stored, there is a guarantee that the various simultaneous users will view the same information.

If it is a client-server architecture, for a web application in the cloud, there is the advantage of security and robustness of data since they are not stored in the same machine as the application but in a remote server. However, internet connectivity must be guaranteed to work with the application since the information only exists on a remote

Table 3.3: Comparison between an on-premise web application and a cloud web application in a client-server architecture

	Client-server on-premise	Client-server cloud
Internet-network connection	Does not need	Requires an Internet connection
Simultaneous users	Possible, if connected on the same LAN	Can be done, provided the device has Internet access
Application installation and updates	Increased difficulty in keeping up-to-date and compatible	The same version is guaranteed for everyone (more accessible update process)
Security of data (loss, malfunction)	cannot be guaranteed	Only if there is a remote server failure
Data backup	Complex	Can be managed/contracted

server.

Table 3.3 summarises the comparison made in the previous paragraphs for a client-server architecture in an on-premise vs. cloud application, taking into account the use of a web application.

In terms of integration with automatic equipment for ToF and HD control, there may be an advantage in a native application. With equipment not prepared to use the Transmission Control Protocol/Internet Protocol (TCP/IP), this architecture shows an advantage over the manufacturer's traditional assembly of autonomous software. In the case of equipment having native and isolated software, it would not facilitate in any way. It would have to be a human agent to manually transfer the values' readings to the judgment software's interface.

If they had a Software Development Kit (SDK), it would be easier because the readings could be programmed to go directly to the judgment software without additional equipment. This case would also allow the same integration with the alternatives, having this equipment where the SDK runs, serving as an interface for the distribution of data [30].

Finally, with the ToF and HD hardware supporting TCP/IP, integration could easily be completed without additional equipment or developments needing support. Possible solutions for a TCP/IP-enabled implementation would be:

- put Webhooks/web services on the judging software side to receive the events [31, 32]. It is prone to errors, in case of a non-treatment that happens momentarily, by the lack of re-processing;

- The equipment should provide endpoints with lists of events, and it would be the responsibility of the judgment software to consult the events and integrate the new occurrences periodically. This facilitates the failures that may occur in connectivity;

- using WebSockets or Message Queuing Telemetry Transport (MQTT) in a publish/subscribe pattern, in an implementation that must be done with acknowledgment of receipt [33, 34].

3.4 Conclusion

Taking into account the examples of current solutions described and given the comparison presented in previous sections, the solution chosen was a web application, in cloud and on-premise (to safeguard the locations that do not know the internet conditions), in a client-server architecture, which will be presented in detail in Chapter 4.

Chapter 4

Proposed solution

This chapter will describe the proposed solution for the project. The user stories (US) of the existing processes will be presented, as well as a description of the proposed architecture, the technical analysis, and the data model description.

4.1 Requirements

The list of requirements was created based on the set of requirements (functional and non-functional) that the client indicated in the various meetings. For a better understanding, we chose to group the requirements by area: "General", "Pre-tournament logistics", "During the competition", "Athletes", "Judges Panel", and "Public". Each group of requirements presents the functionalities and rules necessary in each area. They are as follows:

- General Area

    - The application must have all the necessary templates available for data import.

    - The application must allow exporting the results in Excel and PDF for later printing on paper.

    - The application must replace the existing data with the imported data to ensure data validity.

- Pre-test Logistics Area

    - The competition should be defined only by the person in charge or organizer of the competition.

    - The application must allow the registration of the athletes.

- The registration of the athletes must be possible through the importation of an Excel file.

- Every competition must be configured before beginning.

- Each event must have defined the modalities (type of jump/trampoline) to be evaluated.

- Each competition must have defined the echelons of which it will be composed.

- The application must allow the registration of the existing echelons.

- The application must allow the creation of echelons by importing an Excel file.

- When importing the echelons, the application shall allow the user to choose whether to replace the existing ones or add the imported information.

- The grades must be subject to validation rules when performing the import.

- The grades of the registered athletes should be automatically calculated (assigned by Date of Birth, see Figure 4.1).

- Each competition must have the passage orders defined.

- The application must allow the change of the passing orders, making the management of the groups.

- The application should allow integrating the inscriptions in passage orders.

- If there are missing or incorrect data entries, the application shall allow new integration in the passage orders after the data correction.
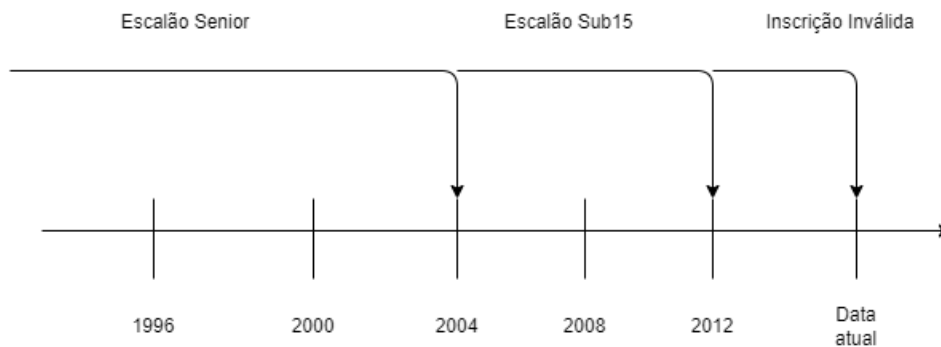

Figure 4.1: Schema of echelon allocation (by Date of Birth until X date)

- During the competition

  - The person in charge or organizer of the event must be able to perform actions during the event.

  - The person in charge of the event must be able to change the passing orders during the event.

- – The person in charge of the event must be able to change the competition settings.

- – The official in charge of the event must be able to change the athletes' notes if necessary.

- – The person in charge of the event must be able to consult the general classifications.

- – The person in charge of the event must be able to search for an athlete's name on the general classifications screen, which must appear highlighted from the others.

- – During the competition, a user must be the "technology adviser" (unrelated to the event organization).

- – The "technology advisor" should be able to monitor the screens available for the public area.

- – The "technology adviser" must be able to monitor the screens available in the athletes' area.

- Athletes

  - – During the event, screens must support the athletes with the application running.

  - – The application must indicate which athlete competes.

  - – The application should indicate the current athlete's final score after the evaluation's registration.

  - – The application should indicate the next athlete in the competition.

- Panel of judges

  - – During the competition, the panel of judges must have access to the application.

  - – The application must allow the registration of the competition notes for each athlete per the judges' panel member.

  - – The application must allow the registration of the scores by each judge or by the panel head.

  - – The application must allow the assignment of finals.

- Public

  - – During the event, the public should be able to consult the ratings in real time.

– Access to the application should be made available to the public through a QR
code.

– The public user must be able to consult the competition rankings on a mobile
device interactively (filter by competition).

4.2 User stories

The list of US was created based on the requirements presented in chapter 4.1. It was
decided to maintain the same grouping performed in the requirements for a better under-
standing. The US's are the following:

1. General

US1.1 As an administrator, I should be able to create users and assign permissions.

US1.2 As a user, I should be able to download templates for data import.

US1.3 As a user, I should have Excel and PDF export options available.

2. Pre-test logistics

US2.1 As the person in charge of the test, I must perform the test setup before the
test starts.

US2.2 As the person in charge of the event, I must be able to register all athletes.

US2.3 As the competition director, I must have the option to import the registrations
of the athletes.

US2.4 As the person in charge of the competition, I must configure the modalities to
be evaluated.

US2.5 As the person in charge of the event, I must configure the existing echelons.

US2.6 As the person in charge of the event, I must have the option to import the
various echelons.

US2.7 As a ringleader, when importing echelons, I must have an option available that
allows me to replace all the existing echelons.

US2.8 As the competition director, I must be able to change the competition passing
orders.

3. During the competition

US3.1 As the person in charge of the event, I must be able to change the competition
passing orders, competition settings, and athletes' notes.

US3.2 As the person in charge of the event, I must be able to consult the classifications of the athletes.

4. Athletes

US4.1 As an athlete, I can see my score at the end of the evaluation.

US4.2 As an athlete, I must be able to identify that it is my turn.

5. Panel of judges

US5.1 As a panel leader, I must be able to enter the marks the panel of judges provides for a given athlete.

US5.2 As a judge, I must be able to enter my notes for a given athlete.

US5.3 As a panel leader, I should be able to assign finals.

6. Public

US6.1 As a member of the public, I should be able to consult the rankings of the current sport interactively.

4.3 Proposed architecture

Since one of the objectives of this work is to proposed and develop an architecture for a scoring system for trampoline competitions, this will be presented in the next sections based on the information obtained and collected in the previous chapters.

The proposed solution consists of a web application, in the cloud and on-premise, in a client-server architecture. The fact that it is a web application will enable several users to use it simultaneously, facilitating access through any device (whether a computer, tablet or smartphone).

Several reasons led to opting for a solution of this type, such as being an agile and simple way for several judges to access at the same time and not being necessary to prepare devices with installations (all the device needs is to have a browser available), having the possibility to develop screens for the public to consult and having the possibility for the platform, later on, to publish the results to ensure the history of the various events. This is a very versatile format, even taking into consideration that the on-premise version will require server management.

Since integration with external hardware (ToF and HD) was excluded from the requirements, it was not necessary to develop an API to transmit the data, which will be manually entered or unaccounted for (depending on the ongoing test). Thus, the two distinct approaches will work as follows:

4.3.1 Cloud

The application in the cloud will be available for access if there is a stable internet connection where the exam is taking place so that no further network configurations are needed, nor a computer simulating a server. Using the web application from the cloud allows all users to have access to the most up-to-date version of the application developed. It will also have the advantage of less complexity in the physical layout since, having all devices access to the internet, everyone will have access to the application without the need to configure local networks.

The database is available in a remote server, enabling the existence of the same database during all the tests and guaranteeing the existence of a record of the history of the classification in digital format. Figure 4.2 presents the outline of the proposed architecture for the version of the cloud. There is an application running on a server where all the browsers will connect and consult the information. This server is responsible for the connection with the database, whether this is on the same server or hosted on another.

As it is possible to see in Figure 4.2, only one database is connected to the application, which will have three types of views available according to the type of user that connects. Ideally, the view dedicated to the judges' panel is accessed by all judges so that they can enter the notes autonomously, after using the most practical pen and paper (as you need to write without taking your eyes off the athlete's performance) and the head of judges approves the entry of the notes.

This approach was used during the testing and trials held at the TCL headquarters. Using this approach for testing ensures that the client will always test and validate the latest version of the project. After indicating the necessary adjustments, these will be made available on the cloud server so that the client can re-test and validate the intervention made.

4.3.2 On-premise

The on-premise application will be available for situations where there is no internet connection in the place where the test takes place or where the available conditions are unknown. The use of the web application from on-premise will enable all users to access the developed application, with the disadvantage that the configuration of the local network will be necessary for users to be able to access it.

The configuration to run on-premises can rely on virtualization or containerization. The former means that computing resources, such as CPU cores and RAM memory, are exclusively allocated to that instance, with an independent chosen (and compatible) operating system. The latter shares resources across containers, enforcing that the kernel

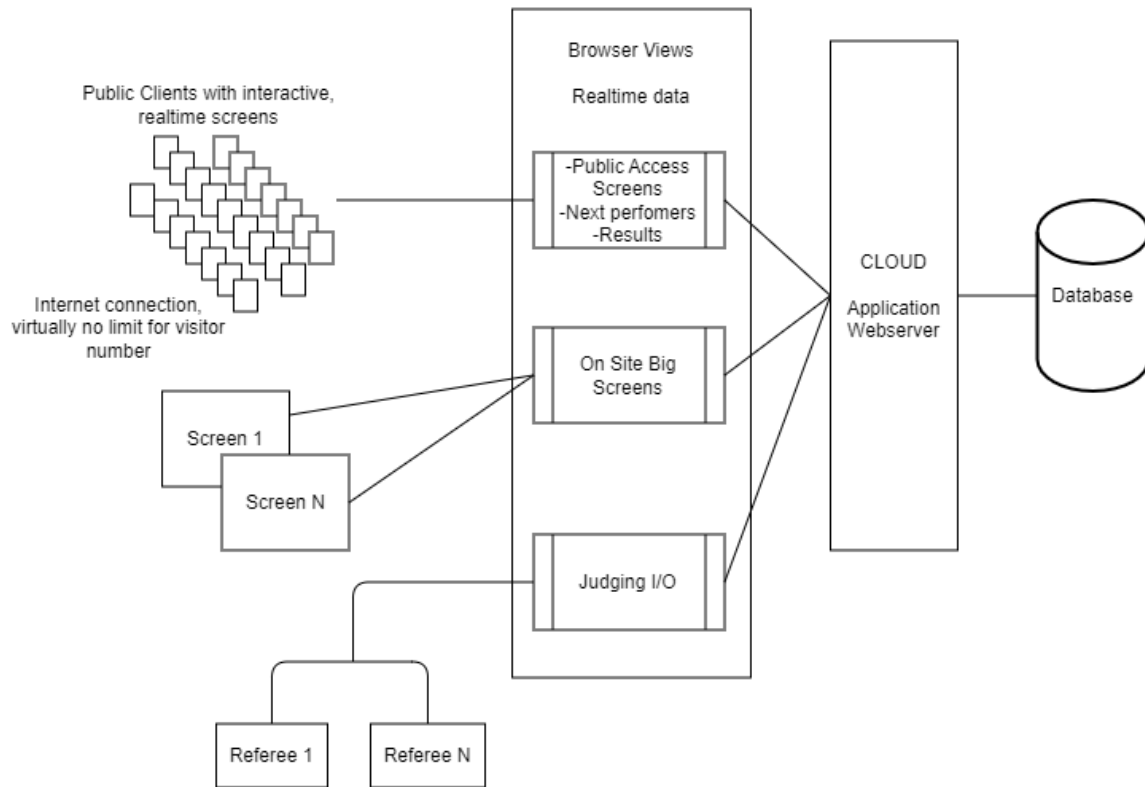Schema 1) Event running with reliable Internet Connection

Figure 4.2: Sketch of the proposed cloud architecture

must be common with the underlying images. As it would be easier to start the service and update to newer versions, it would sacrifice portability [35]. The Virtual Machine (VM) file (or folder) can be more easily copied to a different machine.

Having said this, and as a way to ensure that, in cases where the test takes place in a place without an internet connection, the project was developed and virtualized. Thus, it will be enough to take the computer where the VM is installed and put the virtualization program to work so that the entire network can access the web application. The application will be the same as the application available in the cloud, with the difference that it does not need access to the internet to store the information and that it will have the database instance running locally.

Figure 4.3 presents the outline of the proposed architecture for the on-premise version. An application will run on a server where the judges will insert the information, and the athletes and the public will consult the information provided. This server will connect with the database, which exists locally, and the connection with the API existing in the

cloud server when there is an internet connection.
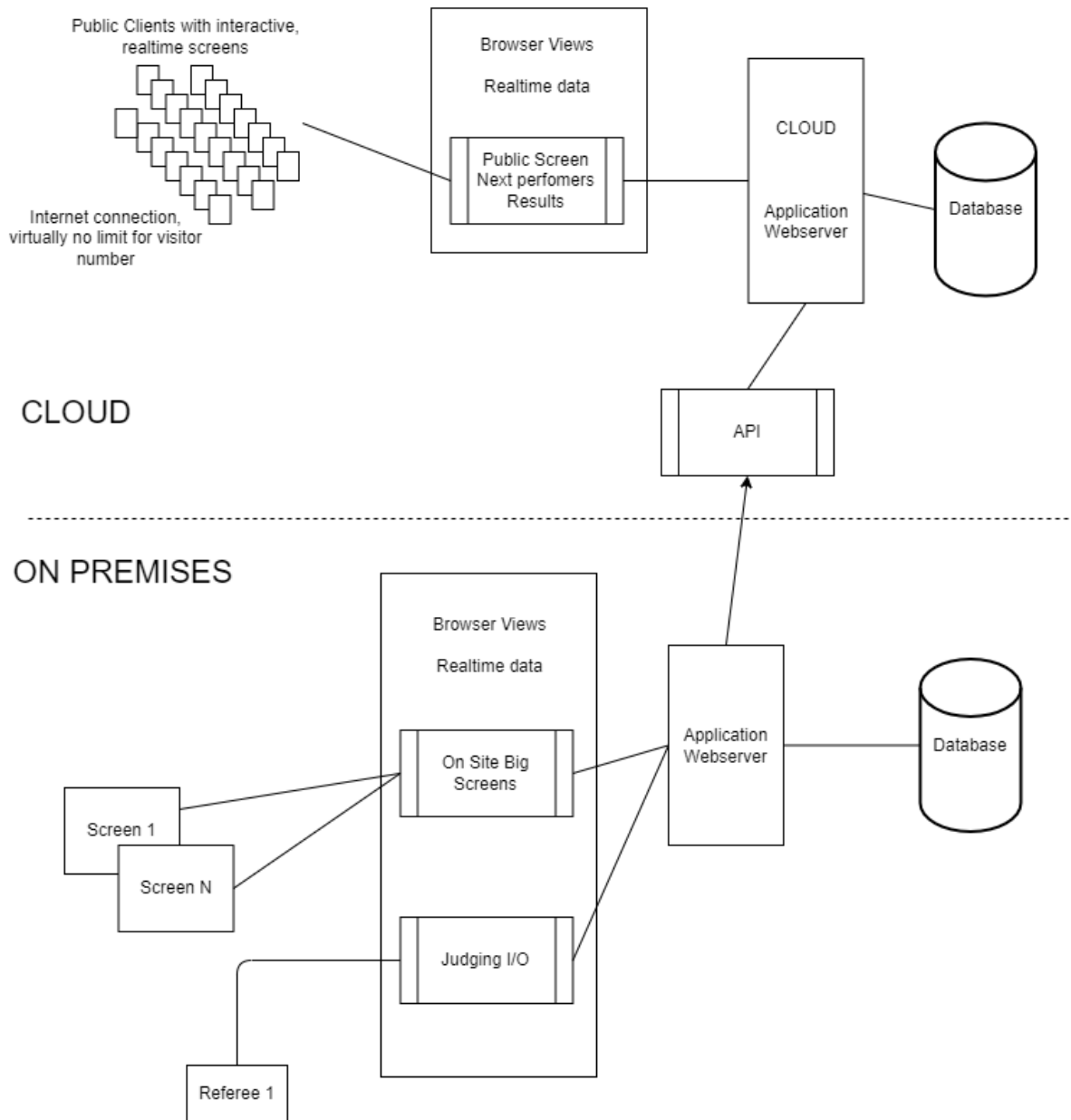
Figure 4.3: Sketch of the proposed on-premise architecture

As it is possible to see in Figure 4.3, there will be two databases: one connected to the on-premise application and one to the cloud application. The views dedicated to the judges' panel and to the public (big screen) will be provided by the on-premise application, while the other view will be provided by the cloud application. In this scenario, the view dedicated to the judges' panel will only be accessed by the head of the panel so that he can insert the notes previously recorded on paper (this was the alternative found to

overcome the limitations of the venues).

4.4   Technological analysis

Based on the proposal, one can perform the technical analysis based on the following points:

- Scalability - being a web application, the technology supports the need for multiple simultaneous accesses, even using a load balancing or a load balancing proxy to have multiple servers managing multiple competitions/events. With a cloud solution, the same application can be used in multiple events around the world;

- Multi-device - as it is a web application, it is easily accessible by a browser (on any device) or by other programs through API requests;

- Interface - being a web application, the interface design will have to be idealized only once, and it may be necessary to adapt it for smaller resolution/size devices. However, the accessibility and ease of use by any type of user (with more or less knowledge) must be guaranteed;

- Rapid Updates - in the cloud solution, it is only necessary to perform software updates in a single place to be available to the entire world. In the on-premise solution, it is necessary to perform the update on the device itself;

- Automatic backups - the cloud solution is easy to manage. Just configure and support the cost without the need for human intervention. As for the on-premise solution must be performed on demand, and the file's existence on the disk must be guaranteed. Alternatives, when there is an internet connection, would be to record the events to a file that is then sent to the cloud or upload the information of the competition/event to the cloud (being then performed the automatic backup of the cloud database);

- Speed - in the case of the on-premise part, the application will depend on the computer where it is installed, as the processing will be done on the machine itself. But in the cloud, it will be possible to have any type of device to access because the processing will already be carried out in the remote server and not in the device itself;

- Processing capacity - not knowing at this stage what level of processing will be needed, this will have to be an issue to be addressed after production use.

Considering all these points and the ones in the 4.3 section, the proposed architecture will present a Model-View-Controller (MVC) architecture, which translates into a separation in Model, View, and Controller. This separation allows each part to focus on only one function, i.e., the View will only serve to present the information defined in the model, which in turn is only "manipulated" in the controller [36].

The advantage of this model is that business rules can be changed without influencing the received data model and its presentation and allowing the same model to be used for several views (making it easier to edit the views). This advantage allows applications to be adjusted to clients without drastic changes to the model [36].

Once the architecture of the project and the type of model used had been chosen, it was necessary to evaluate which technologies were available to develop this project. The choice was limited to Laravel (PHP), JAVA, and ASP.NET.

Laravel is a web application framework with an elegant syntax based on PHP. A framework allows you to have a structure and a starting point without worrying about details, which is the case of Laravel. This framework, focused on offering a unique experience to the programmer, provides several relevant features, such as a base and data abstraction layer, scheduled tasks, and unit and integration tests, among many others [37]. Laravel is based on PHP (Hypertext Preprocessor), an open-source programming language used for web development, and can be embedded into HTML. The code is executed on the server, generating the HTML sent to the client, which only receives the script result [38]. It can be executed on any platform and uses features of several languages, such as JAVA, C++, and C [39].

JAVA is an object-oriented language, which consists of manipulating echelons, objects, attributes, and methods, and is compiled into intermediate code that is then interpreted. Besides being object-oriented, it is described as simple, dynamic, and robust. It is simple to learn, adapts to any project through the modules available, and the programmer does not need to perform memory management because it takes care of that point. In addition, applications are secure and work in multithreading since it was a language created with development for the Web in mind [39, 40].

ASP.NET is a technology developed by Microsoft, which can be implemented through the VB.NET and C# languages, and runs on the server. C# is a programming language released in 2002 and developed for the .Net Framework, originating in C, ending up being identical to other languages such as C++ or JAVA. Like JAVA, C# is an object-oriented language, supporting several features, such as Language Integrated Query (LINQ), lambda expressions, or attributes (annotations), making it not a simple language to use.

After evaluating the available options 4.1, it was decided to choose the Laravel framework because all the options were found suitable for this purpose. It fulfilled all the

Table 4.1: Matrix for deciding on chosen technologies

	Laravel (Framework)	ASP.NET	JAVA
Language	PHP	C#	JAVA
Does it meet all the requirements?	Yes		
Documentation and support methods	It has official, easy-to-understand documentation. There is a large community of developers	It has official documentation, which may become difficult to understand. There is a large community of developers	Has official documentation but may require some knowledge of the language. There is a community of developers.
Developer's familiarity with the technology	There is familiarity with the technology	Not enough knowledge	

necessary list of requirements. Still, it was also where there was more knowledge and more comfort on the part of the development team, requiring a lower learning curve. It is also a framework where it is possible to get support through documentation or through the vast existing community, where members help each other. Besides Laravel, Blade, JavaScript, and Vue were also used, as well as CSS and Bootstrap for page formatting.

To create the frontend, we used HyperText Markup Language (HTML), Cascading Style Sheets (CSS), and Blade. HTML is the language that allows the construction of web pages, using markups to define the structure of the page and the contents that build it [41]. CSS, on the other hand, is a style language to define how elements should appear on the screen. The language gives meaning to the content presented in HTML [42]. To complete the use of CSS, Bootstrap was used. This is a frontend framework that allows responsive development in a simple and fast way [43]. Laravel's Blade is a templating engine. Blade allows you to use PHP code in templates since all templates are compiled to PHP code [37].

JavaScript (JS) is a just-in-time, event-driven programming language that allows you to manipulate the Document Object Model (DOM). It is a language that only "runs" in the browser and is faster since it does not need to communicate with the server. [39]. In addition to using JavaScript, a framework, Vue, was used. Vue is a JavaScript framework that allows you to create interfaces with support in HTML, CSS, and JS. Vue works

based on components and declarative programming, highlighting the reactivity used in the framework: changes are tracked, updating the DOM when the change occurs [44].

In addition to the aforementioned, a rapid application development (RAD) tool was used to build and manipulate the tables, the Grid 4 PHP: this framework uses PHP and jQuery and already contains the basic operations to create, read, update, and delete record (CRUD), facilitating the management of the various grids existing in the project [45]. TailwindCSS was also used, which is a CSS framework that allows the construction of custom interfaces in a fast way. The framework searches for class names to generate the corresponding style and transform it into a static CSS file [46].

Of the various existing solutions for managing grids/tables, this was the one that came closest to the comfort zone of the end user (in this case, the client), who was very comfortable with the use of excel sheets. Thus, the choice of this library was due to the interface allowing that comfort, but based on a database and not an excel file.

4.5 Data Model

The proposed database is a relational database. That is, it is a database where information is stored to create relationships between tables/registers. In other words, in a relational database, each table will have a column that will identify records from other tables, thus creating the relationship between them [47].

For the data layer, we chose to use MySQL. MySQL is an open-source database that can be used in small or large applications. A MySQL database has several advantages: they are quick to install and easy to manage; it is tested in various types of scenarios, conveying reliability; it is scalable and flexible, allowing the use of SQL in conjunction with JSON documents [48].

Figure 4.4 depicts the entity-relationship model of this project. This database consists of nine main tables and an auxiliary table for migrations.

The tables "escaloes" and "configuracoes" serve as configuration tables. The "configuracoes" table supports several event configurations in a key-value format, such as name, date, and place of the event, limit number per group, number of elements per team, number of judges per modality, and the organizing entity of the event. The table "echelons" configure the possible echelons to exist so that later they can be calculated automatically.

The most relevant entities are "inscricoes", "ordens_passagem", "evaluations", "teams," and "classification" since they are the main tables where all the event data will be saved. Since a passage will present multiple evaluations, only the "evaluations" table has a foreign key relative to the "ordens_passagem" table. The others can be related, as it happens between the tables "equipas" and "inscricoes", but only due to another field
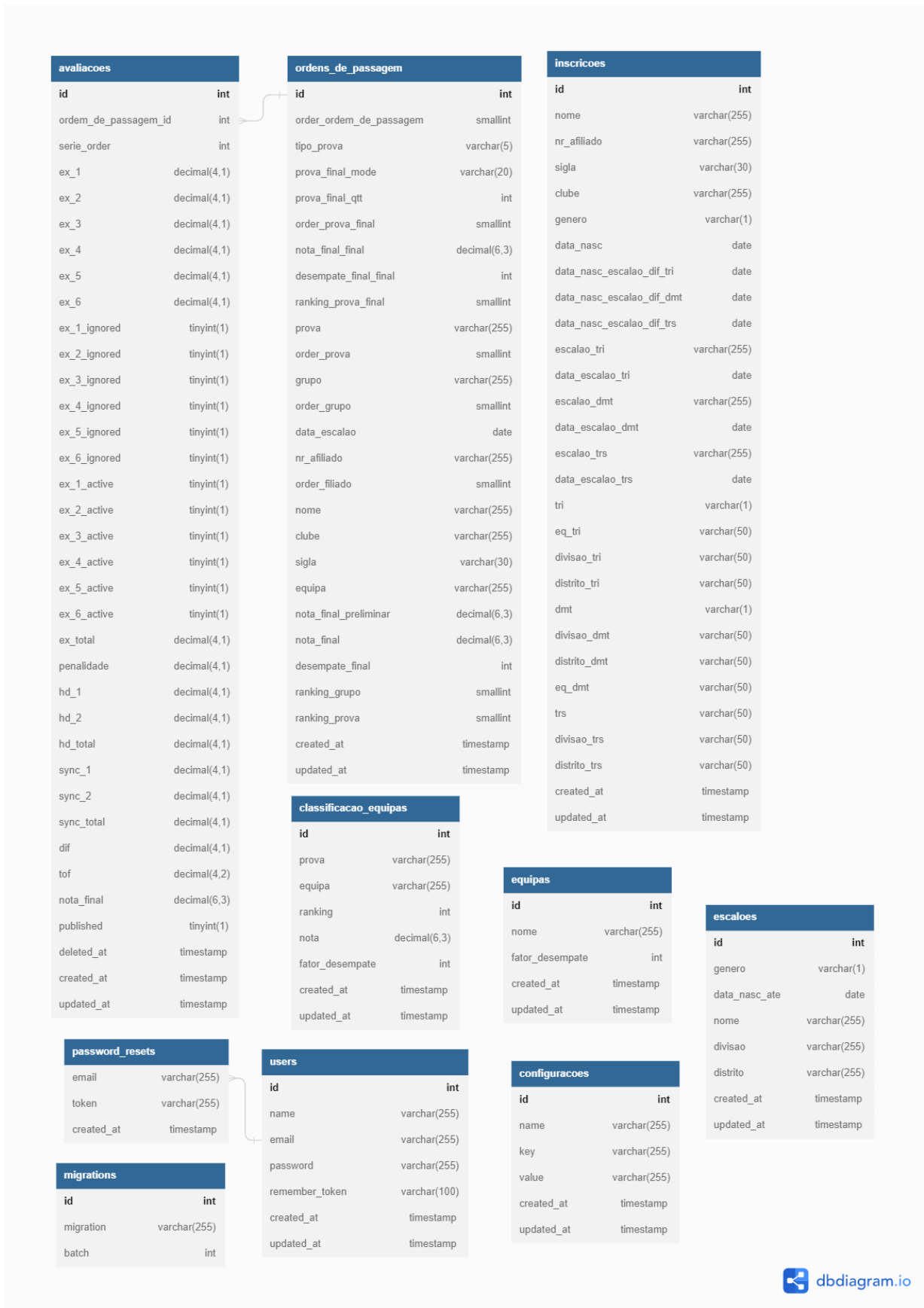
Figure 4.4: Entity–Relationship model database used

other than the primary key field.

However, it was necessary to use denormalized fields to maintain the speed of presenting the data to the public without calculating or processing information from multiple tables. To do so, the "ordens_passagem" and "inscription" tables do not have a connection, which would be a foreign key in the "ordens_passagem" table, but the table where the foreign key would exists now only has the necessary fields related to the "inscription" table.

Also, the final calculations are saved in the database instead of being calculated each time there is a screen where they have to be displayed. That is, the table "avaliacoes" presents fields (ex_total, hd_total, sync_total, and final_grades) where the final calculations necessary for calculating grades and finals are saved. Also, the table "pass_orders" has fields for the recording of the grades calculations, such as the fields "final_grades", "preliminary_grades," and "final_grades".

4.6   Conclusion

Having presented our proposal, the technologies chosen for implementing the project will be presented in the following chapters, as well as the implementation process. The tests performed during and after the implementation of the project will also be presented.

Chapter 5

Implementation

In this chapter, the details of the project development will be presented. The technologies used will be presented, in a brief way, what was developed (according to the requirements and US presented previously) and the tests performed.

5.1 Implementation details

The choice for the implementation relied on a web application with a database service, all bundled in a virtual machine.

This facilitated that the computer could be used as the server for the surrounding clients and for management purposes, such as managing athletes and printing classifications. The infrastructure must be portable, easy to manage and deploy, and autonomous, as the broadband connection was not assured to be present and/or stable and reliable (Figure 5.1).

Figure 5.1: Preparation and check of the Wall Projector devices

As the nature of the event represents that things must go well, no parallel system was possible to put in place simultaneously. For logistics reasons, there were some cautions put into place. Apart from the local network having a wireless access point, every computer had a cabled Ethernet connection.

Given the choice of the language to be used, the implementation of the project did not require a period of adaptation to the chosen technology, only a study of the business rules to be developed.

The screens that will be presented are not developed in a responsive way, with the minimum viewport being decided according to the resolution of TCL's laptops. However, the screens were developed using the viewports available in Bootstrap CSS, with Tailwind CSS being applied only to the screens attached to the equipment.

Homepage

Figure 5.2 shows the project's homepage, where it is possible to import all the data related to the configuration of the tests and download the template used by the application. Figure 5.3 presents an example of the template provided in excel for data import. As you can see, a single file allows the importation of the configurations, the ranks, and the inscriptions. Being possible to change any of them in the specific application screen for a given purpose. Regarding the registrations, the field "Affiliated" is the unique identifier of each athlete, and to identify which competitions the athlete participated in, it was enough to fill with an X the fields "TRI" (individual trampoline) and/or "DMT" (double mini-trampoline). In the case of the TRS field (synchronized trampoline), it was necessary to fill in the pair, that is, immediately identify which athletes would make a pair. The results template would be an excel export, already formatted with the club logos. The content was cleaned and rewritten before the export to present the updated results.

Management page

Figure 5.4 shows the management page of the application backups. here you can backup the current data. To make a backup just assign a name and click on the option, and an SQL file will appear in the grid. The SQL file is generated with all the tables and schemas. This record can then be restored or exported (from the cloud to the device). When restoring, the entire application will be left with the tables, schema, and information from the respective file. It is also possible to import a new file from the device, which will be on the cloud disk and will appear in the grid, being available for restoration or export.
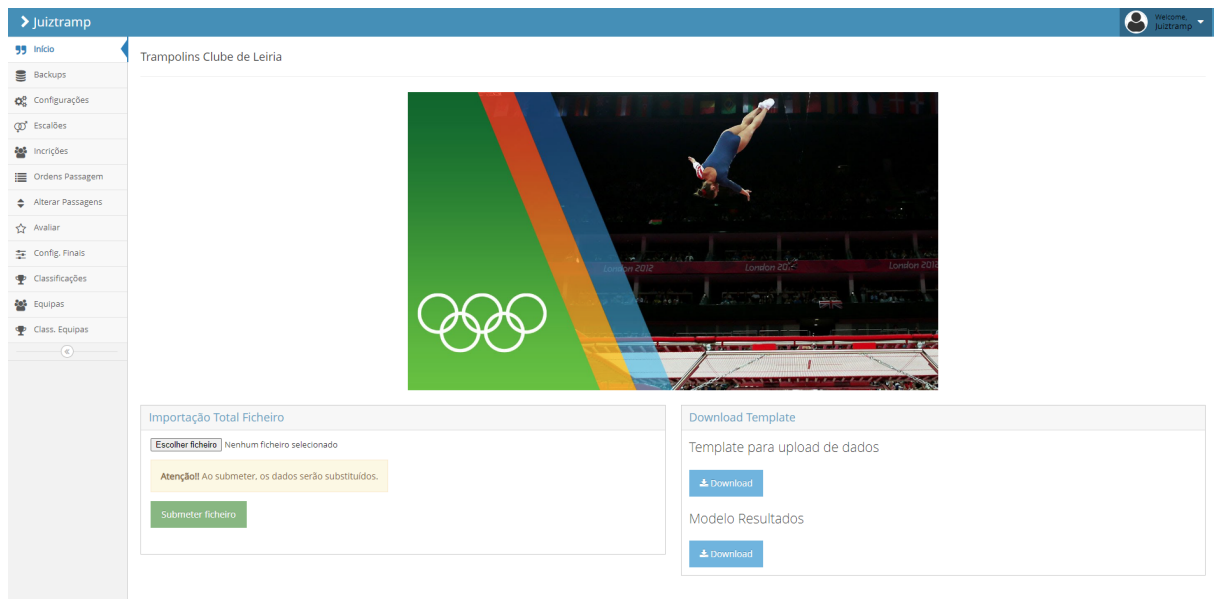
Figure 5.2: Juiztramp homepage

Figure 5.3: Template in XLSX for data import

Configuration

The 5.5 Figure presents the page for the configuration of the events, where it is possible for the person in charge of the event to define the number of judges per modality, the
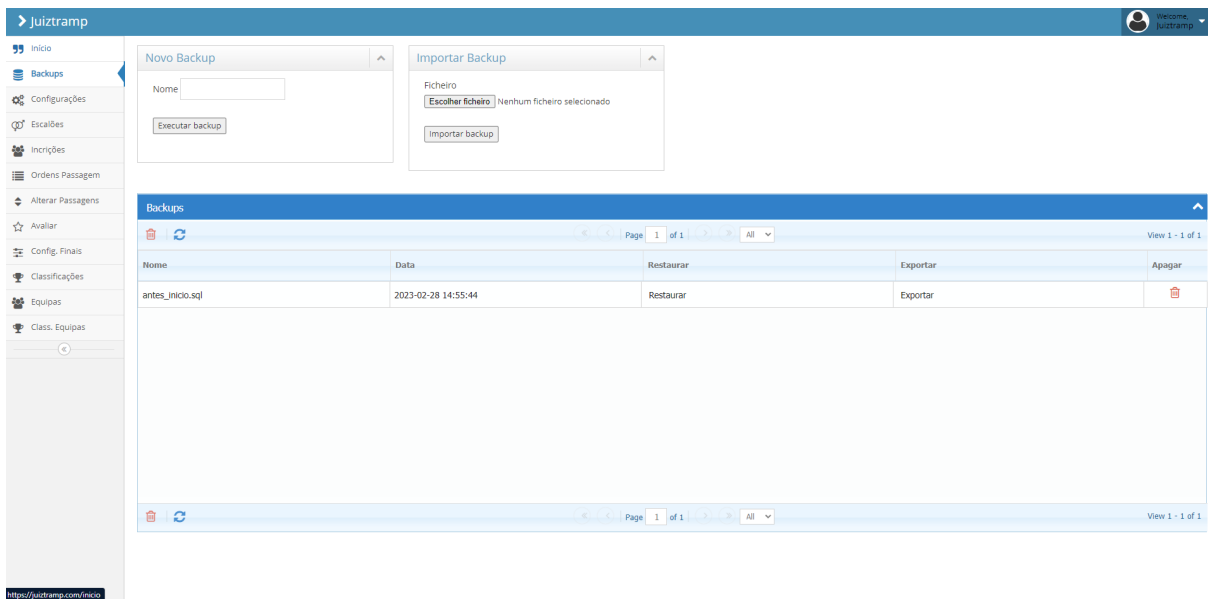
Figure 5.4: Page for managing Juiztramp backups

minimum and maximum number of members per team, as well as the name of the event, date, and place. The existing import screen allows the user to import only the global excel sheet related to the configurations. However, it is possible to edit each record in a simple way directly on the screen, through the pencil icon, a text box appears and allows editing. In the end, saving is done through the enter key or the green icon available on the record line.

Figure 5.5: Juiztramp competition configuration page

Configuration echelons

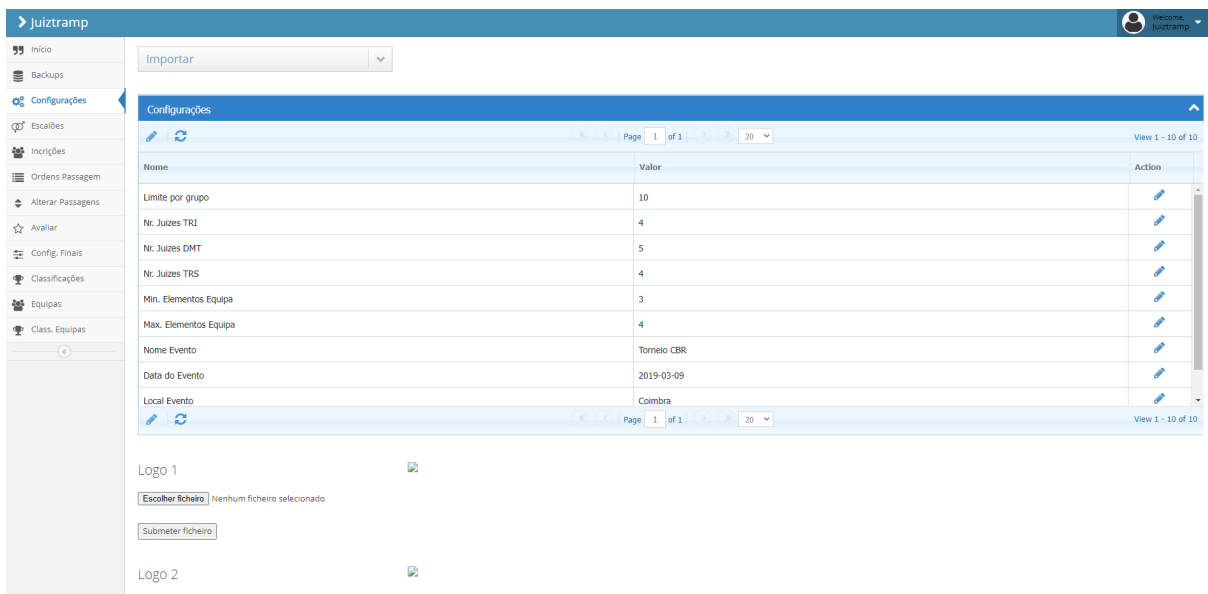Figure 5.6 presents the configuration page for the existing echelons in the trials. The echelons can be inserted in bulk, through the template provided on the homepage, and then managed on this screen. When importing the grades sheet there is available the option to replace or increase the existing grades. If the option to replace is selected, all the records will be deleted before importing the excel records; in case the option is not selected, the imported records will be added to the existing list. If only one stage needs to be changed or added, the competition manager can make this change or add it on this screen, through the actions associated to the grid for that purpose.

Figure 5.6: Juiztramp echelons configuration page

Registration

Figure 5.7 presents the registration page for the athletes who will participate in the event. The registrations are available in a grid, where it is possible to see the category of each modality (which is automatically calculated), which modalities will participate, which are the members of the same team, as well as the personal data of each athlete (district, name, club, date of birth, gender). As with the brackets, the entries are imported through the template provided, and can be added or replaced in whole. Through the grid you can add last minute registrations, edit, delete or view a single record, through the buttons available for that purpose. At the top of the screen, the option to calculate ranks will assign the correct rank to each registration, according to the ranks configured in the application.

The option "Missing integration" will present the instructions for the integration of the missing athletes, being necessary to consult the Pass Orders screen (see Figure 5.8).

Figure 5.7: Page of athlete registrations in the Juiztramp

Figure 5.8: Page of registrations with unintegrated athletes

Athletes' passing orders

Figure 5.9 displays the page with the athletes' passing orders, grouped by competition and group/echelon. In this screen, it is possible to change the registration of the athletes'

passing order by registration or even delete it, however, there are more options available at the top of the screen. The option "Assign group" will generate the groups for each competition, according to what has been defined, in this case, the default will be 10 athletes per group. Each group will have a sequential order, from 1 to 10, being generated the number of groups necessary to include all athletes, e.g., if an event has 25 entries, two groups of 10 and one group of five athletes will be created. The order of passage is then assigned within each group. The option "Clear O.P." will clear all generated passing orders. It is in the "Validate checklist" option that it will be possible to identify the problems that are associated with the entries that have not been integrated (see Figure 5.10). The "Excel" option would export the information available on the screen in a raw form, without formatting, not being relevant for the process of the application, and serving only as a support for the person in charge of the competition, in case he/she wanted to send by email or work the orders outside the application. The "PDF" option would export the formatted waybills with club logos. Each sheet of the PDF will present a different competition. Each competition would also be sorted by group and order of each athlete (see Figure 5.11).

Figure 5.9: Page with the passing orders in the Juiztramp

Edit athletes' passing orders

Figure 5.12 displays the page where it is possible to change the athletes' passing orders. On this screen, you must select the competition so that the groups of the passing orders appear with the athletes ordered. After the lists are displayed, you can change the order through
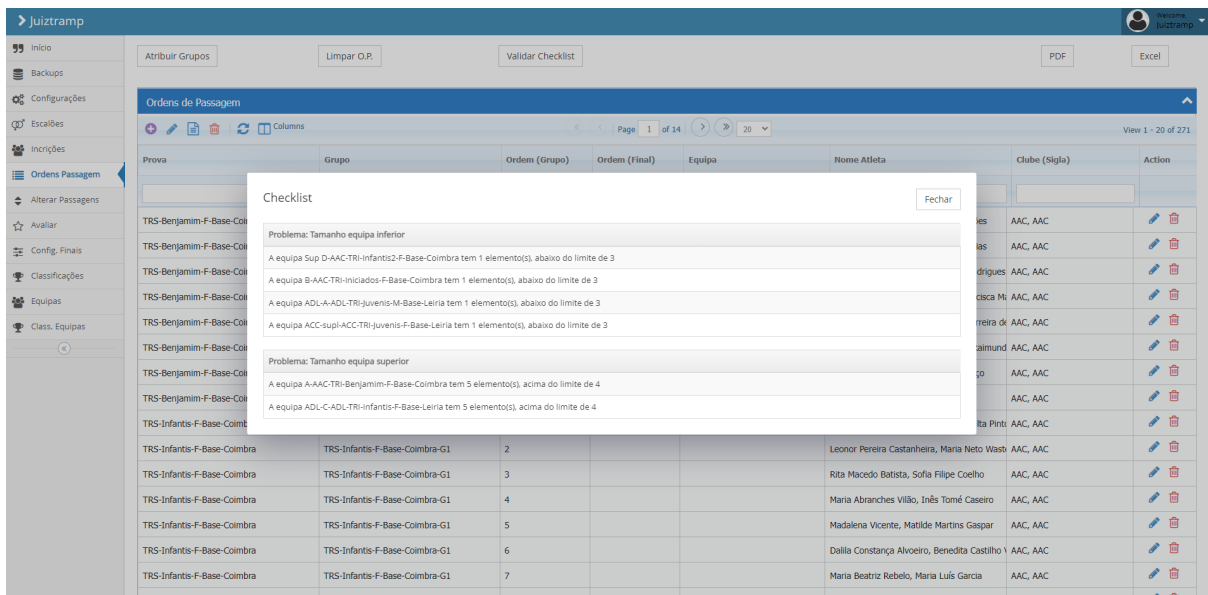
Figure 5.10: Checklist with identified issues in the assignment of passing orders

"drag and drop" and create a new group, just dragging the athlete to the indicated area. At the end of the changes made, these must be saved to be taken over by the application.

Evaluation

Figure 5.13 presents the page where judges will record the athletes' grades. To grade an athlete, the panel leader will have to choose the competition/group in question (the group total is inside parentheses) and select the passing order to which he wishes to assign evaluations (the number between parentheses will be the total number of athletes). An option is available to view the passing orders of the selected group. If it is an individual event, only the data of one athlete will appear, however, if it is a synchronized trampoline, the data of the two athletes will appear, separated by commas. After the selected order of passage, both the judges' fields and the ones configured for the event will appear (in the case of Figure 5.13 four judges are available because they are the ones configured for synchronized trampoline). It will be necessary to fill the fields relative to the marks attributed by the judges' panel, the HD for each athlete, the penalty, the difficulty, and the synchronism for each athlete. It will appear as the indication that the note will be published and you only need to submit the registration (through the green icon). After the submission, the final note will be calculated and the respective field filled. After the two passes (F1 and F2), it will appear the final mark in relation to the calculation of F1 and F2 in the field "Final mark". The field "Final grade FINAL" will be the final grade of the competition considered as final (which may or may not occur, since the competition/modality may not have a final planned), this will be a third passage and

Juiztramp TCL

Prova: TRI-Benjamim-F-Base-Coimbra

Grupo	Ordem	Nome	Equipa
4	1	Bárbara Rodrigues Fonseca	B-AAC-TRI-Benjamim-F-Base-Coimbra
G1	1	Maria João Câmara	F-AAC-TRI-Benjamim-F-Base-Coimbra
G1	2	Kamila R'ched Laroussi	A-AAC-TRI-Benjamim-F-Base-Coimbra
G1	3	Rita Silva Cabaço	E-AAC-TRI-Benjamim-F-Base-Coimbra
G1	4	Maria Carlota Costa	D-AAC-TRI-Benjamim-F-Base-Coimbra
G1	5	Júlia Miguel Pratas	C-AAC-TRI-Benjamim-F-Base-Coimbra
G1	6	Maria Leonor Barbeiro	G-AAC-TRI-Benjamim-F-Base-Coimbra
G1	7	Margarida Dias da Costa	D-AAC-TRI-Benjamim-F-Base-Coimbra
G1	8	Carolina Ferreira de Almeida	B-AAC-TRI-Benjamim-F-Base-Coimbra
G1	9	Francisca Rafael Almeida	A-AAC-TRI-Benjamim-F-Base-Coimbra
G1	10	Maria Leonor Fernandes	F-AAC-TRI-Benjamim-F-Base-Coimbra
G2	1	Marta Marques Pinto	A-AAC-TRI-Benjamim-F-Base-Coimbra
G2	2	Beatriz Santos Oliveira	G-AAC-TRI-Benjamim-F-Base-Coimbra
G2	3	Ana Beatriz Areias	B-AAC-TRI-Benjamim-F-Base-Coimbra
G2	4	Maria Carlota Pires	F-AAC-TRI-Benjamim-F-Base-Coimbra
G2	5	Inês Castro	G-AAC-TRI-Benjamim-F-Base-Coimbra
G2	6	Carolina Costa Figueiredo	E-AAC-TRI-Benjamim-F-Base-Coimbra
G2	7	Matilde Raimundo Cavaleiro	A-AAC-TRI-Benjamim-F-Base-Coimbra
G2	8	Leonor Martins Vitória	C-AAC-TRI-Benjamim-F-Base-Coimbra
G2	9	Laura Miguel Pratas	C-AAC-TRI-Benjamim-F-Base-Coimbra
G3	1	Adriana Oliveira Serra	D-AAC-TRI-Benjamim-F-Base-Coimbra
G3	2	Rita Nogueira Afonso	E-AAC-TRI-Benjamim-F-Base-Coimbra
G3	3	Maria Francisca Machado	E-AAC-TRI-Benjamim-F-Base-Coimbra
G3	4	Alice Gomes Simões	F-AAC-TRI-Benjamim-F-Base-Coimbra
G3	5	Maria Luís Rodrigues	A-AAC-TRI-Benjamim-F-Base-Coimbra

Figure 5.11: PDF exported with the ticket orders

only some athletes will pass according to the configurations previously defined. In case of a tie, it is possible to assign a tie-breaking weight to the selected athlete and create a new reordering. In this screen, a pop-up is also available with information with a caption and shortcuts of the screen (see Figure 5.14).

Configuration of the finals

Figure 5.15 and Figure 5.16 present the page for the configuration of the finals per competition. You must indicate how many athletes will be considered for the final of the

Figure 5.12: Page for changing passing orders in the Juiztramp

Figure 5.13: Page to evaluate athletes in the Juiztramp

competition and echelon. The final average calculation must also be configured: if it is by SUM means that the grade of F3 (final) will be added to the grades of F1 and F2, if it is by RESET means that only the grade of F3 will be counted.
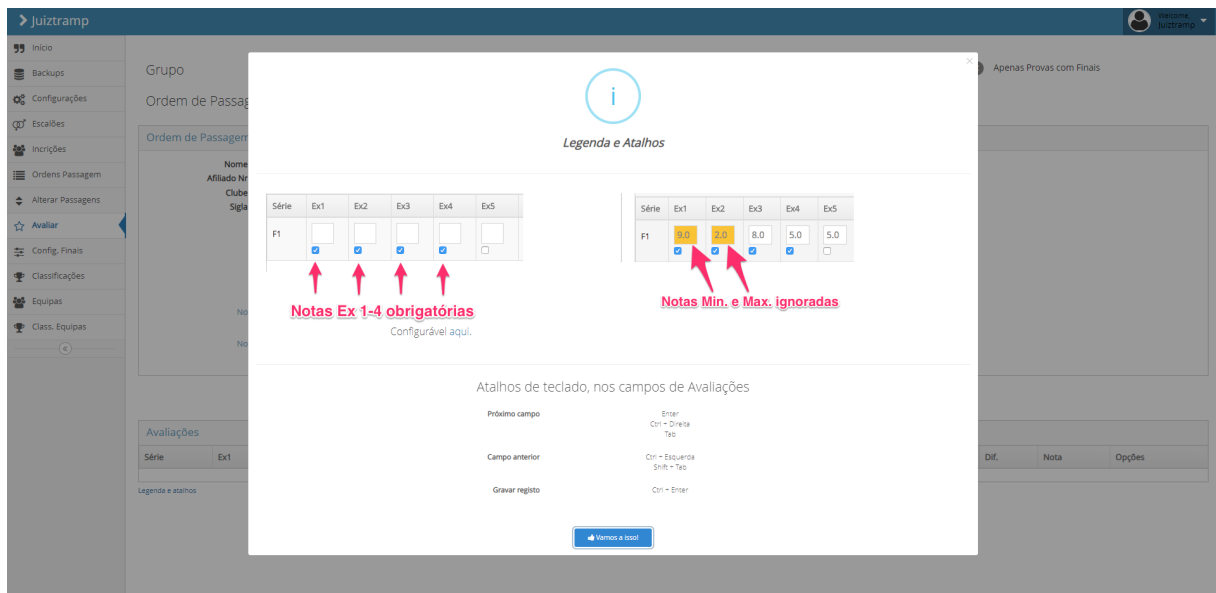
Figure 5.14: Pop-up with information on the evaluation screen
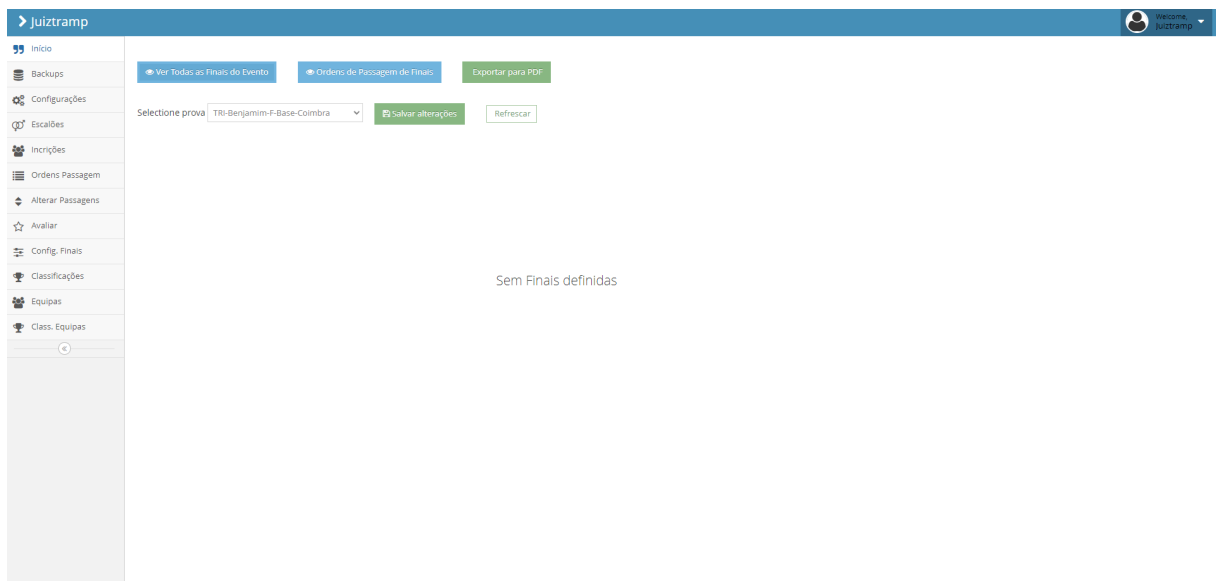
Figure 5.15: Page to configure the finals in the Juiztramp

Classifications

Figure 5.19 displays the page with the classifications of the athletes. The classifications are calculated automatically according to the rules defined in the application and indicated by the TCL. Besides the list with the classifications of each athlete, the athlete that has just been evaluated and the athlete that will jump next will also be visible. There is also an option to consult the passing orders, indicating the number of evaluations of each athlete. It is also possible to update the classifications or filter by competition, only final
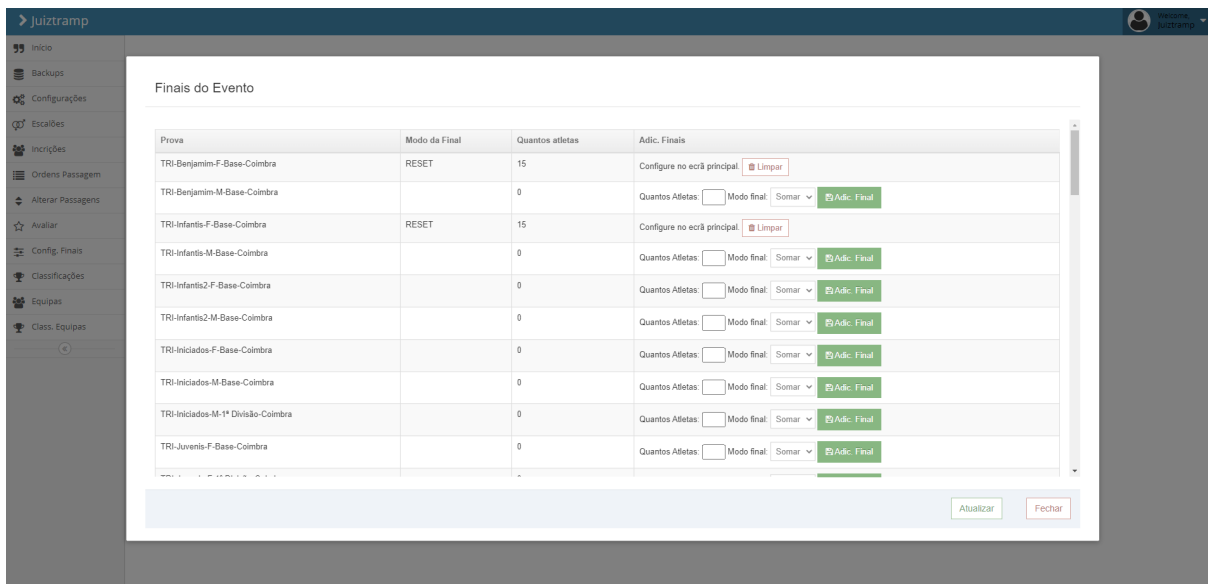
Figure 5.16: Finals configuration pop-up

or athlete; in the case of the search by an athlete, in the grid, the record will only be flagged, instead of displaying matching records. In this screen, there are also options to export the competitions and finals to Excel files (see Figure 5.17) or download PDFs (see Figure 5.18).

There are also links available to display the classifications on projectors (Figure 5.21, Figure 5.22, Figure 5.24 and Figure 5.23), for the public to follow. After choosing the event, the configuration of the seconds to the page, and the number of elements to display, the menu option will be hidden. The configuration of the seconds allows the page to be changed without human intervention and automatically, while the number of elements allows it to be adjusted to the size/resolution of the projector used. In the testing environment, the image was more clear due to the lighting conditions. During the events, the venues' lighting system have strong beams, which results in weaker display on the screen. Nevertheless, it was visible, and it wasn't possible to get projectors with more power due to budget limitations. It is also available the link to the screens that will be available next to the equipment (Figure 5.20). On this screen it will also be necessary to choose the competition, with the menu hidden (accessible through the title of the screen). In this monitor will be visible the athlete that is jumping, the results in real-time (from F1 and F2), as well as the athlete that will jump next.

Teams

Figure 5.25 displays the page with the teams present at the event. This grid allows you to see the teams, and the various sports will have different teams. The grid allows you to

Figure 5.17: Template file for Results of a Competition, in Spreadsheet format
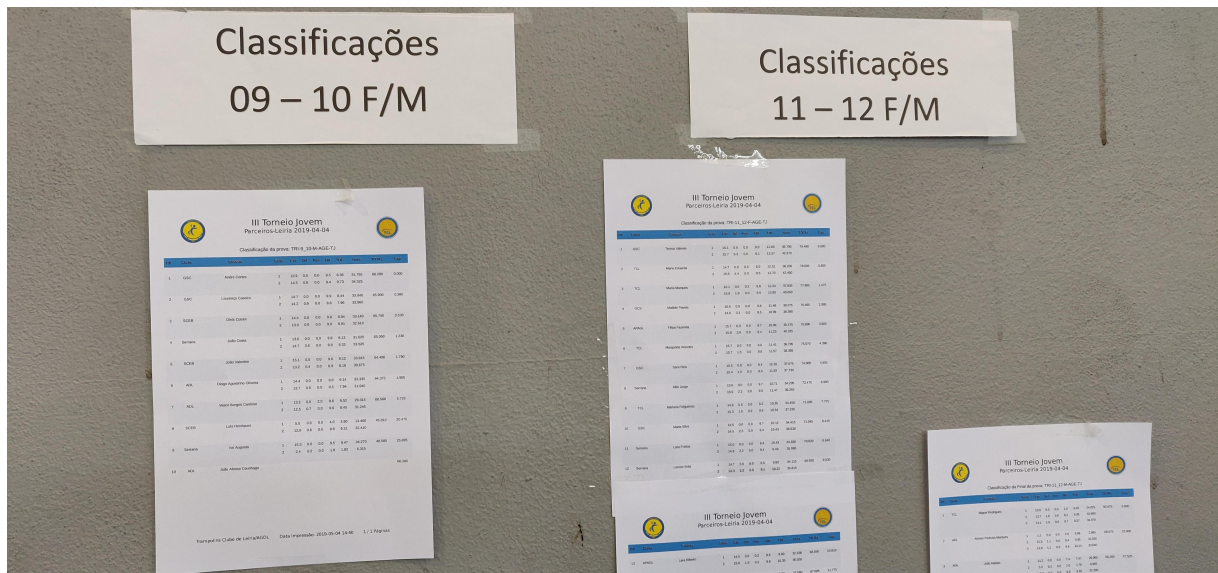
Figure 5.18: Results posted during a competition

change the tiebreaker factor of a certain team or add new teams.

Figure 5.19: Page with the rankings of the athletes in Juiztramp

Figure 5.20: Add screen to equipment

Classification of the teams

Figure 5.26 displays the page with the classifications of the teams present in the event. As well as there is a screen for the general classifications, there is also a screen for the classifications by the team, allowing you to see the grade and the ranking for each team registered in the "Teams" screen.

Figure 5.21: Screen projecting to the public

Figure 5.22: Set up for wall projections

Screen for interactive access

Figure 5.27 presents a screen for interactive access by the public, which was made available at the venue via a QR code. This access had the necessary instructions to access the site, and the user could then consult the live ratings or choose a competition to consult, through the various filters available (Figure 5.28).
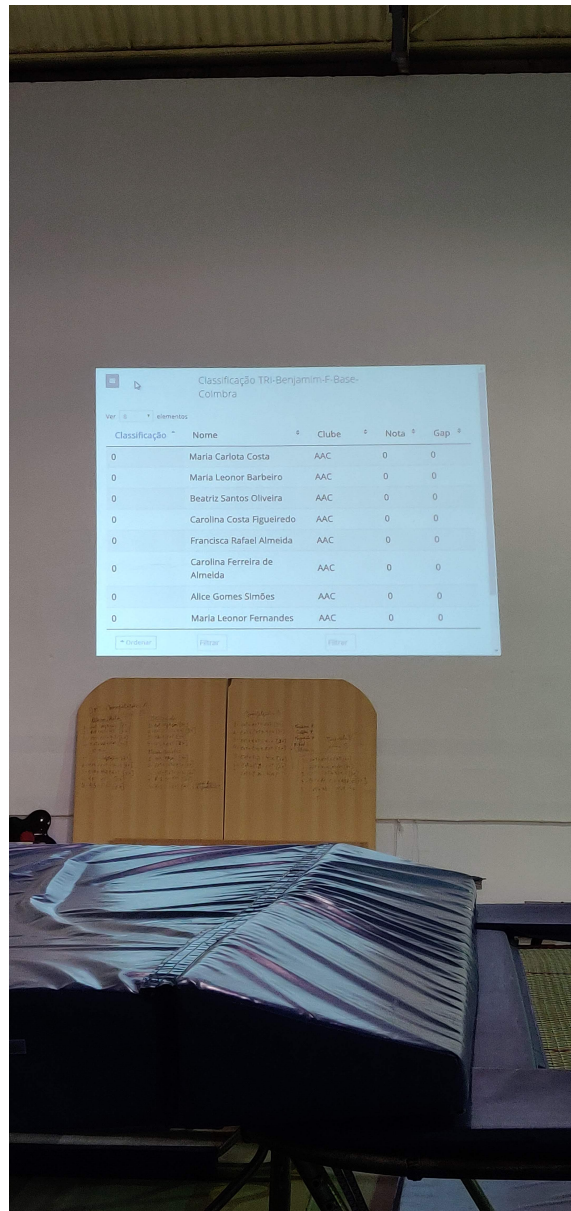
Figure 5.23: Testing wall projection for the audience

5.2   Running tests and analysis

There was a need to ensure that the calculations of the scores, as well as the ratings, would be correct, and there was a need to conduct usability and functionality tests.

Usability tests are tests focused on the evaluation of predefined tasks, based on real contexts, that the users of the system have to perform. In order to keep up with the evolution of technologies, this type of test has served as a source of information to evaluate the UX with the system under development [49].

For the usability tests, user questionnaires were used to understand the experience felt by each user: if the application was intuitive, easy to understand, or if there were

Figure 5.24: Wall projection for the audience, in an actual event

Figure 5.25: Page with the teams registered in Juiztramp

difficulties in understanding how it worked (see Attachment A and Attachment B).

In general, the responses were positive, both from coaches/athletes (Attachment C) and from judges (Attachment D). Regarding the questionnaires answered by the judges (see results in 5.1), a total of eight questionnaires were answered, with the majority stating that the application was easy to learn and handle, as well as allowing easy access to relevant functions. Most also agreed that the presentation of results was done effectively and that it facilitated the assignment of scores. In general, 63% of respondents answered
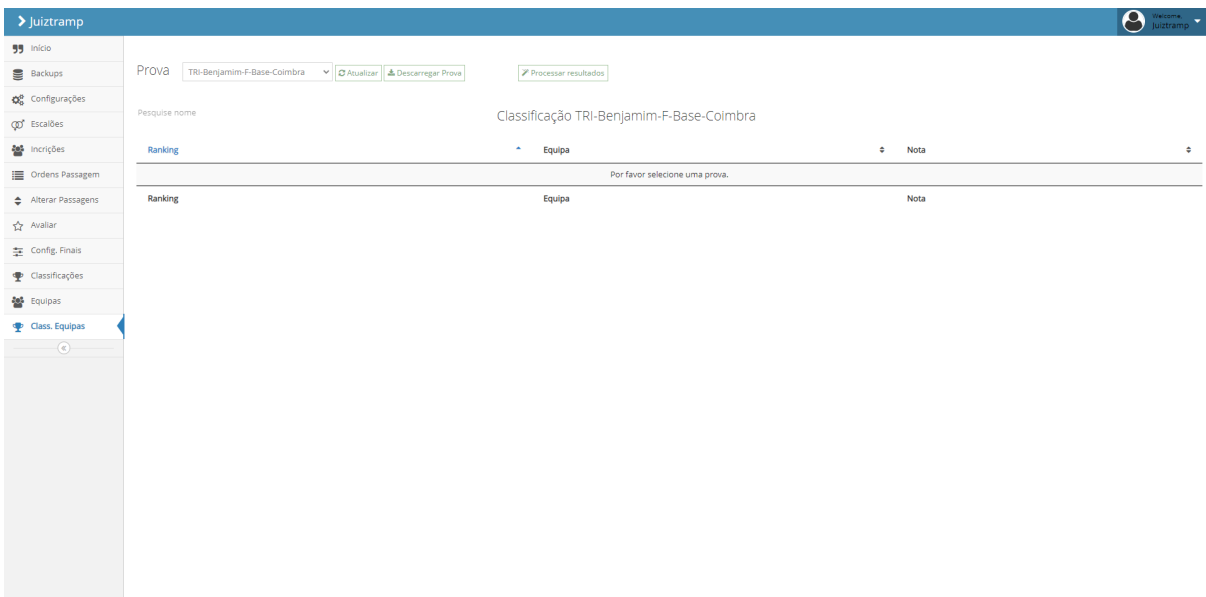
Figure 5.26: Page with the team rankings in Juiztramp

Figure 5.27: Page for audience interaction

that they were very satisfied with the application overall (see Figure 5.29). Out of the eight, four mentioned in their free comments that it would be interesting to have a "next" button when evaluating gymnasts, so that scrolling would not be necessary.

Regarding the questionnaires answered by athletes and coaches (see results in 5.2), a total of 13 questionnaires were answered, in which the majority responded that the application presented the results correctly and in a timely manner. Most also agreed that the information was provided clearly, both in printouts and on large screens. Overall, 92%

Figure 5.28: Live results screen for the audience, available via QR-Code/Link

of respondents said they were very satisfied with the application in general (see Figure 5.30). Out of the 13, one respondent mentioned in the open comments that it would be interesting for the coach to have access to deductions made in each athlete's jumps.

Functionality tests serve to validate whether the defined functionalities have the expected result, i.e. each US is tested as being unique. Whoever does these tests is aware of the information they have to enter and the result they should achieve, without the need to know what is being done between the input and output of the information [50]. Having the final client, in this case, TCL, the knowledge of both parts, we can say that the use of this type of test was an added value.

Since the client was the one with in-depth knowledge about the subject, it was agreed between the parties that he would perform some of the tests, as a way to identify if the obtained result was correct. Even though the information was being passed on what the expected result was, according to the initial data, the client's tests would be extremely relevant. This feedback was fundamental to correct the most diverse situations, which could have an impact during the tests. It was also a way found to guarantee that the use

Table 5.1: Total results obtained from questionnaires completed by judges and club staff

Question	1-Not at all	2	3	4	5-Very much
Easy to learn and handle	0	0	0	2	6
Easy access to relevant functions	0	0	1	1	6
Speed in task execution	0	1	1	3	3
Effective in presenting results	0	0	0	3	5
Facilitated the task	0	0	2	2	4
Facilitated the provision of information	0	0	1	2	5
Overall satisfaction	0	0	0	3	5

Table 5.2: Total results obtained from questionnaires completed by coaches and athletes

Question	1-Not at all	2	3	4	5-Very much
Correct judging results	0	0	0	2	11
Timely judging results	0	0	0	3	10
Information presented clearly	0	0	0	2	11
Overall satisfaction	0	0	0	1	12
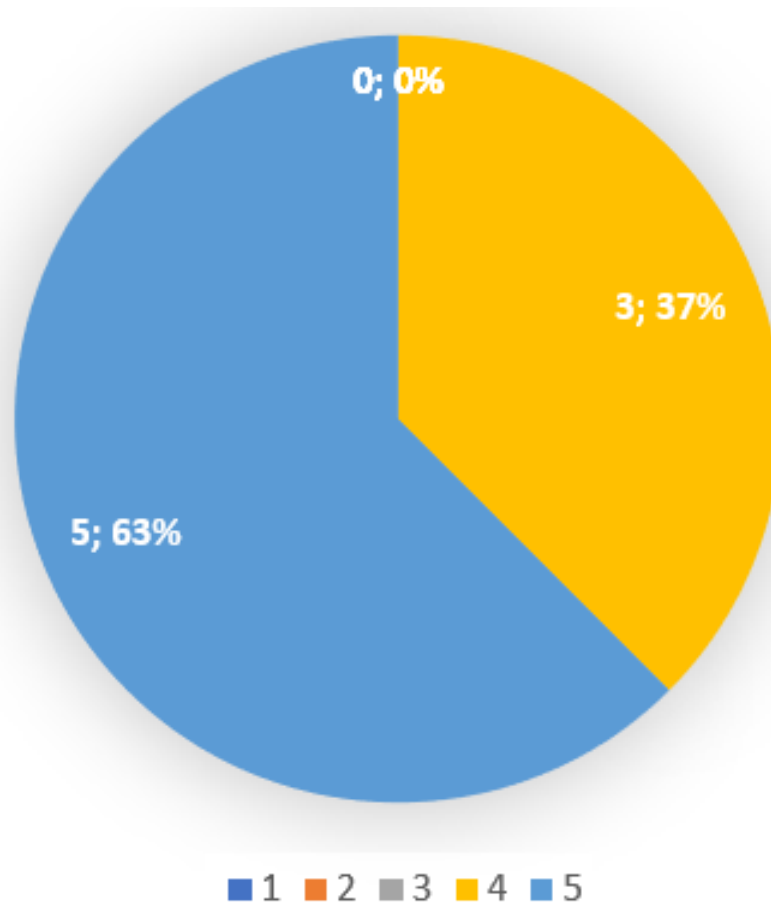
Figure 5.29: Chart with percentages of responses about the overall satisfaction of the application
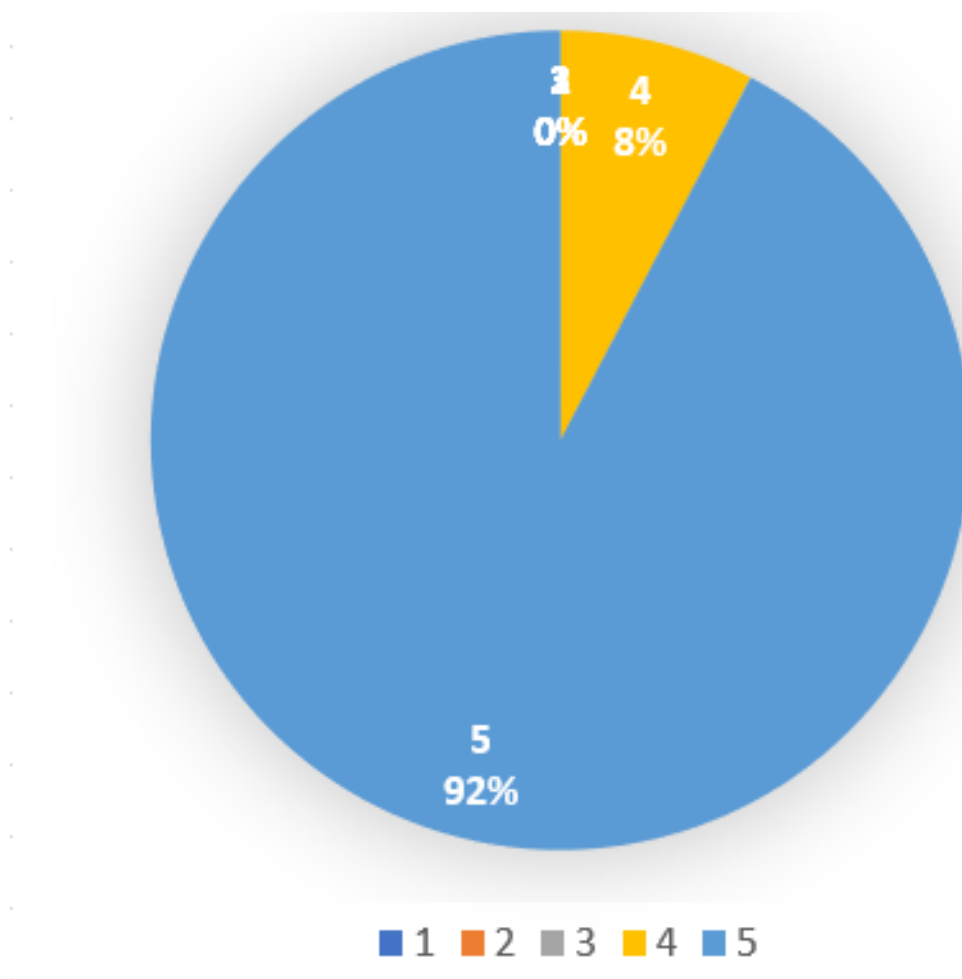
Figure 5.30: Chart with percentages of responses about the overall satisfaction of the application

Figure 5.31: Event preparation check, a day before an event in Leiria.

of the application during real tests (i.e. in production) would occur calmly and without any problems.

It remained for future use or implementation, the collection of previous tests, in Excel format (easy for the client), with all the parameters of evaluations, and final results, so that they can be used as Data Providers (see footnote) in automatic tests.

The project was used in a production context during four different competitions ("Torneio Jovem" 2018, Coimbra Regional, Beach Cup, and "Torneio Jovem" 2019), having been put "to the test" in a real context and obtained a good performance, with positive feedback from the users of the application. In the last event (Leiria 2019), the network was also put to the test, by using a Wireless Lan instead of a cabled (Figure 5.31).

The use of the application by the public present at the competitions was also monitored. To present the collected data, Google Analytics was used. Google Analytics is a platform for collecting data on the use of websites or applications, gathering information on the user who interacts with the page [51].

Figure 5.32 presents a graph with the number of users who accessed the application on May 5, 2019, during the III Youth Tournament, where it can be seen that there is a usage peak before 12pm and another one between 3 pm-4 pm, with almost 60 users accessing it. Figure 5.33 presents a graph with the duration of sessions, during the same day of the youth tournament, where it can be seen that the average session duration is 10 minutes.

It was also possible to ascertain that more than 50 percent of users resorted to using the Chrome browser to access (5.34 Figure) and that around 90 percent of users used a mobile device (Android and iOS) to access the page to consult the results (5.35 Figure).

Figure 5.32: Graphic about the number of users (Google Analytics)
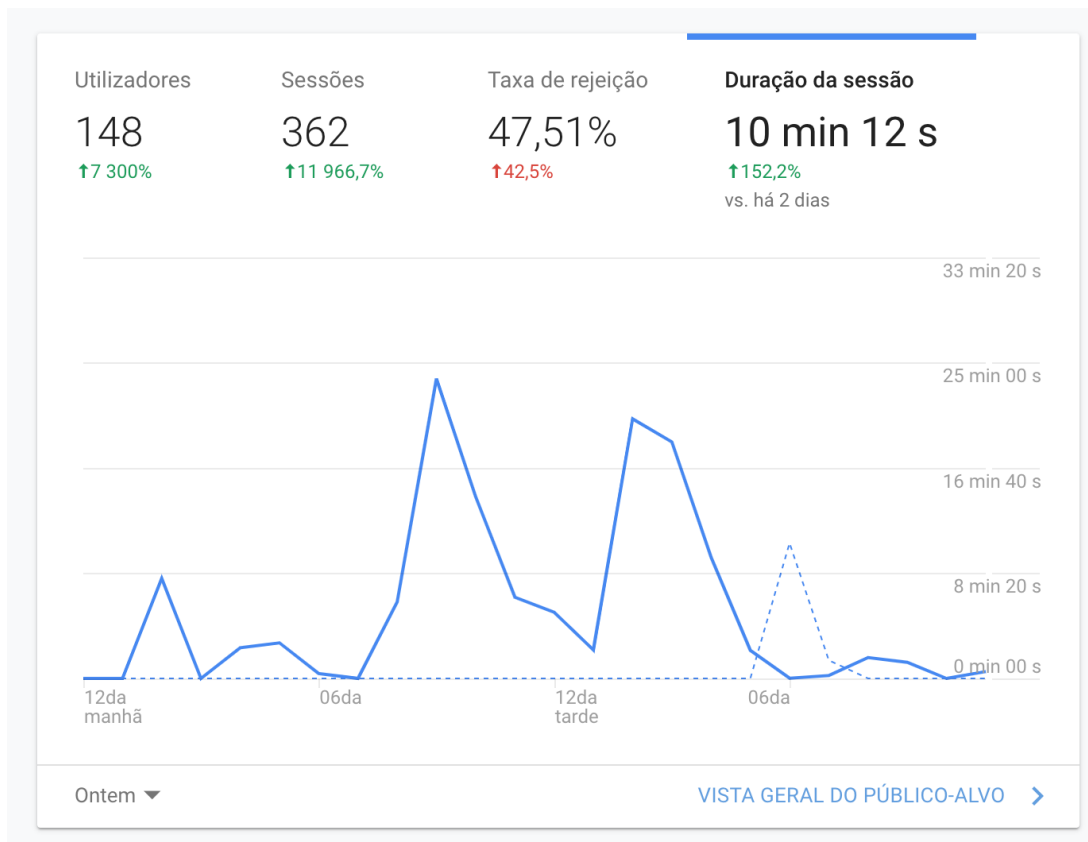
Figure 5.33: Graphic about session duration (Google Analytics)

Figure 5.34: Percentage of users per browser (Google Analytics)

Sistema operativo	Utilizadores	% Utilizadores
1. Android	104	69,80%
2. iOS	33	22,15%
3. Windows	9	6,04%
4. Macintosh	3	2,01%

ver relatório completo

Figure 5.35: Percentage of users by operating system (Google Analytics)

Chapter 6

Conclusions and Future Work

This report presents the project developed during the second year of the master's degree. In general, it can be said that the development went as planned and with the application working in production, i.e., to be used in trampoline competitions.

The main objectives were achieved since all the points were accomplished. There was greater difficulty in the points related to the literature review, due to the scarcity of material, but it was possible to accomplish to some extent. Given the specificity of the topic (use of technology in trampoline gymnastics competitions), the search for articles had to be carried out in parts (the sport itself, the evaluation performed during the competitions, and the technology used to date), in order to obtain the desired information about the current state of the art of the subject.

The project was carried out without major difficulties, with the participation of the "client" in carrying out the necessary tests to ensure that all the information was presented correctly. All the requirements were met, with some that were not possible to develop during the project, such as the integration with the ToF and HD sensors.

A point to develop in the future is the need to integrate the data collected by the ToF and HD sensors in the application so that there is real-time access to the information obtained by them. In the case of HD, it would also be important to the automatic detection of the beginning of the jumps through video recording, also serving as support if the jury felt the need to review the jump.

Another requirement that would be important to develop is the possibility of having an application in the cloud, where the data collected by the on-premises application could be synchronized when it was connected to an internet network. This point would serve as a way to create a centralized system, guaranteeing the digital history of all the evidence registered in the system. In a decade where there is an increasing demand for creating digital archives, maintaining a digital archive in the cloud would be an asset, avoiding the need to export and print Excel sheets, and helping to keep all records easily and available

at a click.

There are also requirements that, not having the same importance or relevance as the previous ones, would be interesting to develop. One of them would be the containerization via Docker of the project, making the distribution easier and allowing having several instances simultaneously, without slowing down the hardware. This containerization would be especially important in the on-premise application since it would no longer be necessary to create and update VMs.

Another point would be the availability of a native mobile application, making it possible to consult the ratings in a more pleasant way for the user. If we consider that there are devices of various sizes and resolutions and that the maintenance of a responsive web application can become complex due to these reasons, the creation of a native application would make the UX more interesting. The creation of the native mobile application would reveal the need for the creation of an API to query the information, which could serve for the integration with other devices in the future or even for the integration of data in the cloud, by the on-premise application.

At the end of the project, it can be said that the balance is positive. The proposed architecture for the project has been achieved, as well as the development of all the critical requirements intended.

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Attachment A

This attachment presents the template questionnaire for coaches and athletes.

JuizTramp

Software de Ajuizamento

Estamos empenhados em melhorar tanto quanto possível, a experiência de utilização do software. Para tal, o seu *feedback* é muito importante.
Por favor, classifique os âmbitos abaixo. Obrigado.

A aplicação apresentou os resultados de ajuizamento corretos.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☐ 5

Nada   Muito

A aplicação apresentou os resultados de ajuizamento em tempo útil.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☐ 5

Nada   Muito

A disponibilização da informação, quer nos ecrãs gigantes, quer nas impressões afixadas, estavam apresentadas de forma clara.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☐ 5

Nada   Muito

Avalie a sua satisfação geral com a aplicação.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☐ 5

Nada   Muito

Opcional: Entende que a aplicação poderia ter melhorias? Deixe comentário abaixo.

_____

_____

_____

Muito obrigado!

Attachment B

This attachment presents the template questionnaire for judges and club staff.

JuizTramp

Software de Ajuizamento

Estamos empenhados em melhorar tanto quanto possível, a experiência de utilização do software. Para tal, o seu *feedback* é muito importante.
Por favor, classifique os âmbitos abaixo. Obrigado.

A aplicação permite uma fácil aprendizagem e manuseamento.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☐ 5

Nada   Muito

A aplicação permite o acesso fácil às funções relevantes.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☐ 5

Nada   Muito

A aplicação permite rapidez na execução das tarefas

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☐ 5

Nada   Muito

A aplicação é eficaz na apresentação dos resultados

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☐ 5

Nada   Muito

A aplicação facilitou a sua tarefa.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☐ 5

Nada   Muito

A aplicação facilitou a disponibilização da informação.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☐ 5

Nada   Muito

Avalie a sua satisfação geral com a aplicação.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☐ 5

Nada   Muito

Opcional: Entende que a aplicação poderia ter melhorias? Deixe comentário abaixo.

_____

_____

_____

Muito obrigado!

Attachment C

This attachment presents the questionnaire answers by coaches and athletes.

JuizTramp

Software de Ajuizamento

Estamos empenhados em melhorar tanto quanto possível, a experiência de utilização do software. Para tal, o seu *feedback* é muito importante.
Por favor, classifique os âmbitos abaixo. Obrigado.

A aplicação apresentou os resultados de ajuizamento corretos.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☑ 5

Nada   Muito

A aplicação apresentou resultados de ajuizamento em tempo útil.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☑ 5

Nada   Muito

A disponibilização da informação, quer nos ecrãs gigantes, quer nas impressões afixadas, estavam apresentadas de forma clara.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☑ 5

Nada   Muito

Avalie a sua satisfação geral com a aplicação.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☑ 5

Nada   Muito

Opcional: Entende que a aplicação poderia ter melhorias? Deixe comentário abaixo.

_____

_____

_____

Muito obrigado!

JuizTramp

Software de Ajuizamento

Estamos empenhados em melhorar tanto quanto possível, a experiência de utilização do software. Para tal, o seu *feedback* é muito importante.
Por favor, classifique os âmbitos abaixo. Obrigado.

A aplicação apresentou os resultados de ajuizamento corretos.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   Muito

A aplicação apresentou os resultados de ajuizamento em tempo útil.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   Muito

A disponibilização da informação, quer nos ecrãs gigantes, quer nas impressões afixadas, estavam apresentadas de forma clara.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   Muito

Avalie a sua satisfação geral com a aplicação.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   Muito

Opcional: Entende que a aplicação poderia ter melhorias? Deixe comentário abaixo.

_____

_____

_____

Muito obrigado!

JuizTramp

Software de Ajuizamento

Estamos empenhados em melhorar tanto quanto possível, a experiência de utilização do software. Para tal, o seu *feedback* é muito importante.
Por favor, classifique os âmbitos abaixo. Obrigado.

A aplicação apresentou os resultados de ajuizamento corretos.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   Muito

A aplicação apresentou os resultados de ajuizamento em tempo útil.

☐ 1   ☐ 2   ☐ 3   ☒ 4   ☐ 5

Nada   Muito

A disponibilização da informação, quer nos ecrãs gigantes, quer nas impressões afixadas, estavam apresentadas de forma clara.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   Muito

Avalie a sua satisfação geral com a aplicação.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   Muito

Opcional: Entende que a aplicação poderia ter melhorias? Deixe comentário abaixo.

_____

_____

_____

Muito obrigado!

JuizTramp

Software de Ajuizamento

Estamos empenhados em melhorar tanto quanto possível, a experiência de utilização do software. Para tal, o seu *feedback* é muito importante.
Por favor, classifique os âmbitos abaixo. Obrigado.

A aplicação apresentou os resultados de ajuizamento corretos.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   Muito

A aplicação apresentou os resultados de ajuizamento em tempo útil.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   Muito

A disponibilização da informação, quer nos ecrãs gigantes, quer nas impressões afixadas, estavam apresentadas de forma clara.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   Muito

Avalie a sua satisfação geral com a aplicação.

☐ 1   ☐ 2   ☐ 3   ☒ 4   ☒ 5

Nada   Muito

Opcional: Entende que a aplicação poderia ter melhorias? Deixe comentário abaixo.

_____

_____

_____

Muito obrigado!

JuizTramp

Software de Ajuizamento

Estamos empenhados em melhorar tanto quanto possível, a experiência de utilização do software. Para tal, o seu *feedback* é muito importante.
Por favor, classifique os âmbitos abaixo. Obrigado.

A aplicação apresentou os resultados de ajuizamento corretos.

☐ 1   ☐ 2   ☐ 3   ☒ 4   ☐ 5

Nada   **Muito**

A aplicação apresentou os resultados de ajuizamento em tempo útil.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   **Muito**

A disponibilização da informação, quer nos ecrãs gigantes, quer nas impressões afixadas, estavam apresentadas de forma clara.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   **Muito**

Avalie a sua satisfação geral com a aplicação.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   **Muito**

Opcional: Entende que a aplicação poderia ter melhorias? Deixe comentário abaixo.

_____

_____

_____

Muito obrigado!

JuizTramp

Software de Ajuizamento

Estamos empenhados em melhorar tanto quanto possível, a experiência de utilização do software. Para tal, o seu *feedback* é muito importante.
Por favor, classifique os âmbitos abaixo. Obrigado.

A aplicação apresentou os resultados de ajuizamento corretos.

☐ 1   ☐ 2   ☐ 3   ☒ 4   ☐ 5

Nada   **Muito**

A aplicação apresentou os resultados de ajuizamento em tempo útil.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   **Muito**

A disponibilização da informação, quer nos ecrãs gigantes, quer nas impressões afixadas, estavam apresentadas de forma clara.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   **Muito**

Avalie a sua satisfação geral com a aplicação.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   **Muito**

Opcional: Entende que a aplicação poderia ter melhorias? Deixe comentário abaixo.

_____

_____

_____

Muito obrigado!

JuizTramp

Software de Ajuizamento

Estamos empenhados em melhorar tanto quanto possível, a experiência de utilização do software. Para tal, o seu *feedback* é muito importante.
Por favor, classifique os âmbitos abaixo. Obrigado.

A aplicação apresentou os resultados de ajuizamento corretos.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   **Muito**

A aplicação apresentou os resultados de ajuizamento em tempo útil.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   **Muito**

A disponibilização da informação, quer nos ecrãs gigantes, quer nas impressões afixadas, estavam apresentadas de forma clara.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   **Muito**

Avalie a sua satisfação geral com a aplicação.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   **Muito**

Opcional: Entende que a aplicação poderia ter melhorias? Deixe comentário abaixo.

É interessante, da prespectiva do treinador, saber as decisões que foram feitas em cada um dos saltos

Muito obrigado!

JuizTramp

Software de Ajuizamento

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Por favor, classifique os âmbitos abaixo. Obrigado.

A aplicação apresentou os resultados de ajuizamento corretos.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   **Muito**

A aplicação apresentou resultados de ajuizamento em tempo útil.

☐ 1   ☐ 2   ☐ 3   ☒ 4   ☐ 5

Nada   **Muito**

A disponibilização da informação, quer nos ecrãs gigantes, quer nas impressões afixadas, estavam apresentadas de forma clara.

☐ 1   ☐ 2   ☐ 3   ☒ 4   ☐ 5

Nada   **Muito**

Avalie a sua satisfação geral com a aplicação.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   **Muito**

Opcional: Entende que a aplicação poderia ter melhorias? Deixe comentário abaixo.

_____

_____

_____

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☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   **Muito**

Opcional: Entende que a aplicação poderia ter melhorias? Deixe comentário abaixo.

De difícil leitura ao público (~~...~~)

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☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   **Muito**

Opcional: Entende que a aplicação poderia ter melhorias? Deixe comentário abaixo.

CABECALHO DO CADERNO DE Resultados mais elaborado com hipotese de em baixo colocar Patrocinadores e apoios de Entidades.

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☐ 1 ☐ 2 ☐ 3 ☐ 4 ☒ 5

Nada   Muito

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☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5

Nada   Muito

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☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5

Nada   Muito

Avalie a sua satisfação geral com a aplicação.

☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5

Nada   Muito

Opcional: Entende que a aplicação poderia ter melhorias? Deixe comentário abaixo.

Quando é inserida a nota, aparece essa
nota no ecrã e após x tempo
automaticamente aparecer a listagem
de ginastas e / os resultados
Is Penss que não está a   **Muito obrigado!**
acontecer mas também
ainda não tive muito contacto
c/ o programa

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Software de Ajuizamento

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☐ 1   ☐ 2   ☐ 3   ☐ 4   ☑ 5

Nada   Muito

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☐ 1   ☐ 2   ☐ 3   ☐ 4   ☑ 5

Nada   Muito

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☐ 1   ☐ 2   ☐ 3   ☐ 4   ☑ 5

Nada   Muito

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_____

_____

_____

Muito obrigado!

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☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   Muito

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☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   Muito

Opcional: Entende que a aplicação poderia ter melhorias? Deixe comentário abaixo.

_____

_____

_____

Muito obrigado!

Attachment D

This attachment presents the questionnaire answers by coaches and athletes.

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Por favor, classifique os âmbitos abaixo. Obrigado.

A aplicação permite uma fácil aprendizagem e manuseamento.

☐ 1 ☐ 2 ☐ 3 ☑ 4 ☑ 5

Nada   Muito

A aplicação permite o acesso fácil às funções relevantes.

☐ 1 ☐ 2 ☐ 3 ☑ 4 ☑ 5

Nada   Muito

A aplicação permite rapidez na execução das tarefas

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☑ 5

Nada   Muito

A aplicação é eficaz na apresentação dos resultados

☐ 1 ☐ 2 ☐ 3 ☑ 4 ☐ 5

Nada   Muito

A aplicação facilitou a sua tarefa.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☑ 5

Nada   Muito

A aplicação facilitou a disponibilização da informação.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☑ 5

Nada   Muito

Avalie a sua satisfação geral com a aplicação.

☐ 1 ☐ 2 ☐ 3 ☑ 4 ☐ 5

Nada   Muito

Opcional: Entende que a aplicação poderia ter melhorias? Deixe comentário abaixo.

_____

_____

_____

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☐ 1   ☒ 2   ☐ 3   ☑ 4   ☐ 5

Nada   Muito

A aplicação permite rapidez na execução das tarefas

☐ 1   ☐ 2   ☒ 3   ☐ 4   ☐ 5

Nada   Muito

A aplicação é eficaz na apresentação dos resultados

☐ 1   ☐ 2   ☐ 3   ☒ 4   ☐ 5

Nada   Muito

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☐ 1   ☐ 2   ☒ 3   ☐ 4   ☐ 5

Nada   Muito

A aplicação facilitou a disponibilização da informação.

☐ 1   ☐ 2   ☐ 3   ☒ 4   ☐ 5

Nada   Muito

Avalie a sua satisfação geral com a aplicação.

☐ 1   ☐ 2   ☐ 3   ☒ 4   ☐ 5

Nada   Muito

Opcional: Entende que a aplicação poderia ter melhorias? Deixe comentário abaixo.

_____

_____

_____

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☐1 ☐2 ☐3 ☐4 ☒5

Nada   Muito

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☐1 ☐2 ☐3 ☒4 ☐5

Nada   Muito

A aplicação facilitou a disponibilização da informação.

☐1 ☐2 ☐3 ☐4 ☒5

Nada   Muito

Avalie a sua satisfação geral com a aplicação.

☐1 ☐2 ☐3 ☐4 ☒5

Nada   Muito

Opcional: Entende que a aplicação poderia ter melhorias? Deixe comentário abaixo.

Existir um botão "next" para ir automaticamente p/ o próximo ginasta; Quando clicar no "enter" ao introduzir notas, considerar a validação da nota; "tab" dar até o "✓"

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Nada   Muito

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☐1 ☐2 ☐3 ☐4 ☒5

Nada   Muito

Avalie a sua satisfação geral com a aplicação.

☐1 ☐2 ☐3 ☐4 ☒5

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Opcional: Entende que a aplicação poderia ter melhorias? Deixe comentário abaixo.

_____

_____

_____

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☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   Muito

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☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   Muito

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☐ 1   ☐ 2   ☐ 3   ☒ 4   ☐ 5

Nada   Muito

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☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   Muito

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☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   Muito

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☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   Muito

Avalie a sua satisfação geral com a aplicação.

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☒ 5

Nada   Muito

Opcional: Entende que a aplicação poderia ter melhorias? Deixe comentário abaixo.

A aplicação poderia/deveria permitir que se passasse automaticamente para o ginasta seguinte (evitando scroll down/up)

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☐1 ☐2 ☐3 ☐4 ☒5

Nada   Muito

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☐1 ☐2 ☐3 ☐4 ☒5

Nada   Muito

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☐1 ☐2 ☐3 ☒4 ☐5

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☐1 ☐2 ☐3 ☐4 ☒5

Nada   Muito

Opcional: Entende que a aplicação poderia ter melhorias? Deixe comentário abaixo.

_____

_____

_____

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☐1 ☐2 ☐3 ☐4 ☒5

Nada   Muito

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☐1 ☐2 ☐3 ☐4 ☒5

Nada   Muito

Opcional: Entende que a aplicação poderia ter melhorias? Deixe comentário abaixo.

Botns Next Givashj;
"TAB' até validar;

Muito obrigado!

Inês Gonçalves Rodeiro

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☐ 1   ☐ 2   ☐ 3   ☒ 4   ☐ 5

Nada   Muito

Opcional: Entende que a aplicação poderia ter melhorias? Deixe comentário abaixo.

- Troca de escalões; Passar rapida/ para o ginasta a seguir

Muito obrigado!