



**NOVA**

**IMS**

Information  
Management  
School

# MGI

---

**Mestrado em Gestão de Informação**

Master Program in Information Management

Application Toolbox architecture for Football Coaches

João Gonçalo Teixeira Manso

Dissertation proposal report presented as partial  
requirement for obtaining the master's degree in  
Information Management

NOVA Information Management School  
Instituto Superior de Estatística e Gestão de Informação  
Universidade Nova de Lisboa

**NOVA Information Management School**  
**Instituto Superior de Estatística e Gestão de Informação**  
Universidade Nova de Lisboa

**APPLICATION TOOLBOX ARCHITECTURE**  
**FOR FOOTBALL COACHES**

by

João Gonçalo Teixeira Manso

Dissertation proposal report presented as partial requirement for obtaining the master's degree in Information Management, with a specialization in Information Systems and Technologies Management

**Advisor:** *Professor Doutor* Vítor Manuel Pereira Duarte dos Santos

October 2021

## ACKNOWLEDGEMENTS

Throughout the writing of this dissertation, I have received a great deal of support and assistance.

First of all, I would like to thank my supervisor Professor Vítor Manuel Pereira Duarte dos Santos for his guidance through each stage of the process, significant comments, all the knowledge shared with me and valuable criticism that enabled me to develop the quality of my thesis.

I would like to thank the football coaches that accept to be interviewed, coach João Paulo, Sandro Jesus and Paulo Nunes, your participation was very important.

Thanks to my colleagues from NOVA IMS João and Gonçalo for these two great years together of our master's degree, all the group works, the exams and courses that we pass together, thank you for your support and friendship.

Thank you to my friends Gonçalo, Guilherme, Henrique, Pedro, João Afonso, João Luís, Maria, Diogo e Sebastião, for all your support and friendship along all these years, and especially thank you Gonçalo, for helping me finding the coaches to interview, you were a valuable help.

I am thankful to my girlfriend Leonor for helping me collecting information, reading my thesis, correcting my grammar, offering valuable advice and all the support and motivation and always being there when I needed it most.

I owe my deepest gratitude to my parents Ivone and Fernando for their support and encouragement, my sister Sara for being my role model and her husband João.

To all my family thank you, my grandparents, uncles, and cousins.

And finally, I want to thank my dog Marley for keeping me company every day while I wrote the thesis.

## **ABSTRACT**

This study is to create an application Toolbox architecture for football coaches to help them improve the performance of their teams. Football has been reinventing itself with the implementation of technology. Information Systems are starting to take part in football in many sectors, especially in one that influences a lot the way the game is going to be played, the one managed by football coaches. Technology helps to improve the show experience and develop game analysis by football coaches. This field is going to pass through the training, health, and performance of football teams. This research will make a state of the situation concerning technology used by football coaches, identifying the currently used technologies and what could be implemented, and eventually measuring the impact of these devices on the performance of the football teams.

## **KEYWORDS**

Technology; Football; Coaches; Performance; Teams; Success

# INDEX

1. Introduction.....	1
1.1. Background.....	1
1.2. Motivation.....	1
1.3. Objectives.....	2
1.4. Research Questions.....	2
2. Literature Review.....	3
2.1. Football.....	3
2.1.1. Concept.....	3
2.1.2. Performance.....	4
2.1.3. The role of the coaches.....	5
2.2. Information Systems for football.....	6
2.2.1. Types and Applications.....	7
2.2.2. Team Management Applications.....	8
2.2.3. Tactical and Performance Management Applications.....	8
2.3. Computer-Based Technologies for football.....	9
2.3.1. Physical tracking devices.....	9
Global Positioning Systems (GPS).....	9
Local Positioning Systems (LPS).....	10
Optical-based camera Systems.....	10
2.3.2. Computational technical approaches.....	11
Artificial Intelligence (AI).....	11
Virtual Reality (VR).....	12
2.4. Case Study “Barça Innovation Hub”.....	13
2.4.1. Pixellot Air.....	13
2.4.2. Pixelott AI technology.....	14
2.4.1. WIMU PRO.....	15
3. Methodology.....	16
3.1. Design Science Research.....	16
3.2. The strategy of the research.....	17
4. Software toolbox Architecture for football coaches.....	18
4.1. Assumptions.....	18
4.2. Toolbox.....	20
4.2.1. Identification of the context.....	20

4.2.2. Identification of aspects for team improvement .....	21
4.2.3. Identification of the requirements.....	24
4.2.4. Identification of the technology.....	25
4.2.5. Physical Tracking Devices: .....	25
4.2.6. Computational technical approaches .....	27
4.3. Demonstration.....	30
4.4. Validation.....	33
4.5. Discussion .....	34
5. Conclusions.....	37
5.1. Synthesis of the developed work .....	37
5.2. Limitations .....	37
5.3. Future Work.....	38
Bibliography/References.....	39

## LIST OF FIGURES

Figure 1- Camera Pixellot Air.....	13
Figure 2- WIMU PRO .....	15
Figure 3- Design Science Research model – adapted from (Peffer, 2006).....	16
Figure 4- Methodology diagram.....	17
Figure 5- Toolbox architecture .....	20
Figure 6- Flowchart for Identification of the context.....	20
Figure 7- Flowchart for Identification aspects for team improvement .....	21
Figure 8- Flowchart for Identification of the requirements.....	24
Figure 9- Flowchart for Identification of the technology.....	25
Figure 10- Application Toolbox Context selection .....	30
Figure 11- Application Toolbox Aspects evaluation.....	30
Figure 12- Application Toolbox final reports.....	32

## LIST OF TABLES

Table 1- Health aspects .....	22
Table 2- Tactic aspects .....	22
Table 3- Training aspect .....	23
Table 4- Performance aspects.....	23
Table 5- Requirements per context for each aspect.....	24
Table 6- Physical Tracking Devices .....	25
Table 7- Computational technical approaches .....	27
Table 8- Evaluation table.....	29
Table 9- Context and Technology relation .....	29
Table 10- Context and Aspect relation.....	31
Table 11- Choice of Technology .....	31
Table 12- Context and Technology relation .....	32

## LIST OF ABBREVIATIONS AND ACRONYMS

<b>AI</b>	Artificial Intelligence
<b>ANN</b>	Artificial Neural Network
<b>BIH</b>	Barça Innovation Hub
<b>DSR</b>	Design Science Research
<b>DTS</b>	Decision Tree Classifier
<b>EPTS</b>	Electronic Performance & Tracking Systems
<b>FA</b>	Football Association
<b>FCB</b>	Futbol Club Barcelona
<b>FIFA</b>	Fédération Internationale de Football Association
<b>GPS</b>	Global Position System
<b>IS</b>	Information Systems
<b>IT</b>	Information Technology
<b>KPI</b>	Key Performance Indicator
<b>LPS</b>	Local Position Systems
<b>OBCS</b>	Optical-based Camera System
<b>SVM</b>	Support Vector Machine
<b>UN</b>	United Nations
<b>UWB</b>	Ultra-Wideband
<b>VR</b>	Virtual Reality



# **1. INTRODUCTION**

## **1.1. BACKGROUND**

Since human beings start to talk until the appearance of the first computers, information technology (IT) never stopped improving. People over the years start linking IT with computers and nowadays, computers, data centres, servers, database management systems and specialized software applications are managed by IT departments, systems, and databases administrators. Can be stated that Information technology is now an important part of human lives since supports modern businesses and is an essential key to the process (O'Brien & Marakas, 2010).

Information Systems (IS) can be considered as a mix of IT and human activities. IS are very important for people since support us in numerous subjects like management, operation and decision making. Information systems are categorized into three parts: Management Information System, Decision Support System and Executive Information System (O'Brien & Marakas, 2010). If the IT evolution was observed along the times can be noticed that various information systems, such as global IS data warehouses, enterprise resource planning and enterprise systems, expert systems, geographic information systems, and office automation have emerged in the business world. In 1999 Bill Gates stated that the information system is the digital nervous system of the business. This indicates that information systems have a vital role in the current business (Gates, 1999). Information Systems nowadays are present more and more in many industries such as manufacturing, building, transportation, storage, finance, education, health, social security, culture, entertainment and finally sports.

Information Systems are starting to become more and more present in football. Investments in sports technology exceeded \$1 billion in 2015. Football Coaches have more ways to employ their knowledge since technology is evolving and devices and IS have been created to facilitate their job. Currently, some details can only be noticed while using technology tools and that is what can make the difference for football clubs that have it. So, because of this is important to understand if Information Systems are making that many differences while applied on football teams, in which fields the football coach takes more advantage of these technologies and how Information Systems help football coaches to improve the performance of their teams (Magee, 2015).

## **1.2. MOTIVATION**

This study can reveal itself to be substantially important for the scientific community, since with the use of IS by football clubs, implicitly the human body is being studied. The type of data that will generate will ask a lot of questions not only about tactics and performance but also about the human body, for example, how players react in different types of scenarios and their physical capacity.

This study compared to other studies, will pass through studying all IS that are applied in football, classify each one of them to understand which one is more used by football coaches and which one has more impact on the performance of football teams. And as the objective to help previous managers to identify in an easier way the IS that is most useful for the way they are training their teams.

Information systems are taking football to another level. They are very important for the football world and science but also for society and sports in general. These technologies bring competitiveness among athletes and consequently a better show to football fans (Coutts, 2014).

In a practical view, this study is important to understand in which areas football coaches see that these kinds of technologies are more useful to help them on their day-to-day job, and what data give more knowledge to the background of a football team (Coutts, 2014).

To reinforce the already existing Information Systems but not very used by all types of clubs, from not professional to professional clubs, this study has theoretical importance of giving extra value to data analysis and bring some answers to details that only can be noticed while using technology tools.

This study would be useful as a reference for football coaches to establish or improve the use of club information systems in order to increase the performance of their teams.

### **1.3. OBJECTIVES**

In order to understand how the football coaches, use the data and how it helps to improve the performance of their teams, this research is to develop an application toolbox architecture that could be used by any football team and help football coaches take the best from their teams and players.

To achieve this goal, the following intermediate steps were defined:

1. Study the football coach's information requirements.
2. Study the Information Systems that are being used by football coaches.
3. Build an architecture software toolbox for football coaches.
  - a. Validate the toolbox.

These objectives identified in this section intend to help answer the following research questions presented in the next section.

### **1.4. RESEARCH QUESTIONS**

The main question is: "Which is the best software architecture to help a football coach? "

To answer this main question, three sub-questions will be analysed:

1. How do Information Systems help football coaches to improve the performance of their teams?
2. What type of data is more important?
3. Which Information Systems can facilitate some processes?

## 2. LITERATURE REVIEW

This chapter will consist of three principal themes. First, it is going to be presented the history of football, its origins rules, evolution, and the impact that bring to the world followed by football performance, individual and team performance, and finally the role of football coaches. The second main theme is information systems in football, types, and applications. Finally, the third part, in line with IS will pass through the computer-based technologies in football, distinguish physical tracking devices and computational technical approaches.

### 2.1. FOOTBALL

#### 2.1.1. Concept

Football is a game disputed between two teams composed of 11 players, in which the teams try to win the game by introducing the ball into the opposing team's goal and don't let the opposing team score in their goal. Win the team that score more goals and concede fewer goals (*Cambridge Dictionary*, 2020). The origins of modern football came from England where the Football Association was founded in October 1863, "the official beginning of what is now the most successful participant and spectator sport in the world" (Kitching, 2015). However, there is evidence that around 2,000 years ago, a rudimentary ball was already kicked in China (FIFA, 2007). The first set of draft rules were adopted while the creation of the Football Association, free-kick was allowed at goal after "fair catch" of the ball, throwing of the ball to a teammate, and running with the ball in hand after a fair catch or a catch of the ball "on first bound". These rules are much different nowadays, but one of them that has changed the most was the rule that did not recognise a specialist goalkeeper, the one nearest the goal defend it (Kitching, 2015).

As times go by a lot of new rules has changed and many new technologies have been introduced. In today's context, football is constantly becoming more and more competitive, and more than the principal "actors" that are fans, players, coaches and referees, more factors are starting to make difference among the "beautiful game" as football is known. Those factors are one of the reasons why football is the most famous sport in the world and a new rising industry that pushes thousands of millions of euros and seems like is never going to stop growing, with transfer records beaten in all transfer windows. One example is Manchester City that has spent more on defence than 52 countries. They sign Benjamin Mendy for 52 million, Kyle Walker for 54 Million, Danilo for 27 Million, Ederson for 35 Million and Laporte for 57 Million, making a total of 225 Million pounds. Despite being an industry of this size, football is simple to play by anyone regardless of their social status since everyone can practice the sport becoming something easily accessible to all social classes (Smith, 2018).

Football has an enormous impact on human life. Furthermore, football is at the top of team sports at the professional level (World's Most Popular Sports, 2010). FIFA is composed of more member countries than the UN (Stein et al., 2016). One example of its greatness is the World Cup 2006 in Germany that brought together 3 359 439 spectators. The matches were played in 12 beautiful stadiums. Also, the estimated worldwide audience were more than 3 billion people watching the matches. Were played 64 matches by 32 teams from all over the world that provide a 147-goal show

(FIFA, 2006). Therefore, we can see that Football has the power to move people from all over the world.

There are 326,527 football clubs officially registered all over the world in FIFA. More concretely two hundred and sixty-five million male and female players combined with five million referees and officials making a total of two hundred seventy million people that are actively involved in the “beautiful game”, 4% of the world’s population (FIFA, 2001).

Football fans are incredible, they fill stadiums, make a lot of noise, and do their best to make sure their team win. Players are admired or hated by all, because of their mistakes and achievements. They are the most important piece on this board game surround by the other “actors”. Referees, probably the most hated profession of all, fans never agree with their decisions. And finally, coaches. The ones who have the most insecure job. If there are no results, are the first to get sacked (Kattuman et al., 2019).

### **2.1.2. Performance**

As football is gaining more and more popularity around the world, football organizations and researchers are trying to enhance the overall performance of their players. Performance is a crucial aspect in any sport, it is the individual or team performance that will be challenged against the opposition team. Numerous variables can affect an athlete’s performance, like overall environment, weather, and stadium’s atmosphere, the psychological status of the player/team, recent injuries or even health conditions and personal issues. Football coaches are worried about technique and health performance metrics since they are crucial to measuring the global performance of their teams. The technical performance field consists of player activities through the match, like the number of successful passes, length of ball position, number of passes between players, and the number of shots the player seeks to score a goal. Technology has simplified the practice of quantifying football players’ performance. Two categories of technologies are used to monitor health-related performances. Players’ physiological performances are defined primarily using wearable technologies. The physical performance of the player is determined using both wearable and in-field technologies. By understanding the relationship between technology and performance as well as how and where it is being applied helps in enhancing the supervising process, which leads to increasing the global performance of the players (Almulla et al., 2020).

#### Individual performance and Team Performance

Nowadays football is a highly challenging game in which footballers are exposed to various events that require total intensity and power production, speed, agility, balance, stability, flexibility, and enough level of endurance (Jovanovic et al., 2011). To reach the top in professional football, massive training is required to enhance performance. The footballer individual performance is a very important subject even though football is a collective sport. When the Individual performance is viewed in detail fields such as health, physical capability, psychological mentality, tactical intelligence, speed is analysed to take the best from each player, since football asks for different types of players for each position and in each position (Brink et al., 2010). Differing on the position performed and the team’s kind of play, footballers have the chance to play well in one or various regions of the game. For example, some

strikers concentrate only on shooting and on the other hand box-to-box midfielders are frequently participating in all areas of the game. On a match stage level, players are evaluated corresponding to their skill to increase above the regular degree of performance determined for all of the footballers in at minimum one of the three areas considered: defensive activity, distribution and attacking activity.

With the collective of individual performances, the team performance is obtained. Is by the combination of the work that each player implements on the pitch that the team can win the match. Even the world best players cannot win a game by them self's if they score a lot of goals in a match, their team has to make impossible the opponents score, by defending the midfield, the penalty area, the goal area and of course the goal. When overall team performance is analysed is taking into consideration tactical parameters like, number of passes, pass accuracy, types of passes, passes in specific areas, tackles won/lost, shots on/off target, also tactical parameters like ball position, ball position in a certain area of the pitch, attacking third entries, tactical ability like offensively, transition, defensively and finally also has to take in consideration the factors that influence the performance like, the opponent that could be a successful or non-successful team regarding their ranking, and sometimes the ranking don't mean nothing since it is common in football the worst team win the best since "the ball is round and the game is long". Also, the match location, home or away, the type of competition if a league game or knock-out, fatigue and psychological factors (Carling et al., 2015).

### **2.1.3. The role of the coaches**

The role of football coaches was very important in the history of the sport. It is a very unstable profession with a high risk of getting dismissed. If the team is not getting good results, they are the first ones getting sacked. However, studies on sports team performance have shown that through many sports and league competitions, teams that switch their coaches after a drop in performance, do not make better on average than teams that do not switch their coach in a comparable situation (Kattuman et al., 2019).

The way coaches communicate in different manifestations verbal or non-verbal can influence positively or negatively their player's development (Allan & Côté, 2016). The leadership football coaches demonstrate is very important. Leadership is defined as "the behavioural process of influencing individuals and groups towards set goals" and make part of the coaches' roles. Coaches should use efficient communication to encourage positive relationships with, and among, players by improving a sports performance model concentrated on human development (Turner et al., 2019). Motivational states are crucial components in team performance, supportive, for example, the managing of team effectiveness and anxiety self-control noticed that positive feedback from a coach facilitates to sustain a positive emotional status of the group, which can enhance performance (Kattuman et al., 2019).

In professional football, the constant chase for success requires the efficient collection, analysis and interpretation of information gathered on player performance to manage decision-making and generate feedback for training prescriptions and match planning strategies (Carling et al., 2015). Consequently, coaches should concentrate on training duration to increase interval duration capacity in elite football players. Even though there is reported proof that individual intensity scores are crucial in relation to overtraining and injury, further research is required to investigate whether this also leads

to a better expectation of performance in football. (Brink et al., 2010). Several studies have stated that leadership adjustments are unrelated to performance. Nevertheless, averaging through teams masks the importance of the leader because some new leaders may improve performance, although some do the opposite. Therefore, the issue of leadership succession must be studied at the detailed level of team processes. In Fact, qualitative studies have argued in advance the importance of leaders for performance (Kattuman et al., 2019).

## **2.2. INFORMATION SYSTEMS FOR FOOTBALL**

Can be called an information system (IS) to any structured consolidation of people, software, hardware, data resources, network communications, and policies and procedures that store, retrieves, transforms, and disseminates information in an organization. Currently, people count on innovative IS to communicate with each other by using a variety of physical devices (hardware), information processing and procedures (software), communications channels (networks), and stored data (data resources). Today's IS are typically thought of as having something to do with computers, however, we have been using IS since the beginning of civilization. Still, nowadays we make regular use of IS that have zero to do with a computer one example is the card catalogues in a library (O'Brien & Marakas, 2010).

This IS as defined above start to appear in the football world and is changing the way football coaches to train and prepare their teams and is starting to differ a lot from the past years (Kattuman et al., 2019). Not just because of the emerging of different types of football players and distinct ways of thinking from each manager but also because of the technologies that they have access to. These technologies that were once quite simple and fulfilled their functionality with the evolution of football are starting to get outdated since AI and VR technologies can bring much better precision than previous technologies (Claudino et al., 2019). Through the past decade, considerable development of computer-aided tracking technology for the examination of player activity during training and match-play has occurred. High-quality systems such as multiple camera semi-automatic systems, local position measurement (LPM) technology and global positioning system (GPS) technology enable a fast recording and handling of the data of all players' physical contributions during an entire match or training session. Technology is starting to take part in football; those tools are starting to get a lot of capabilities to fulfil the need of this technology era of football (Buchheit et al., 2014).

Sports technology is believed to improve team performance by enabling superior measurement, monitoring, and planning of performance. According to the Analytical Research Cognizance, the Worldwide Sports Analytics market is expected to grow by 40.1% during 2016–2022, reaching approximately \$3.97 billion by 2022. Information Systems are one of the factors that are starting to become part of football. Along with technological evolution, football also saw the need to modernize and adopt new technologies, with the aims of turn sports fairer and improving their quality. Sports Technology as football is in constant expansion and development (Infoholic Research, 2017).

Clubs needed to evolve to be able to keep up with their competition, they start to modernize their technology and are taking advantage of all the capabilities that can be provided to achieve their goals. There is a great evolution in the understanding of the physical and technical needs of football (Coutts, 2014).

Information systems create players information databases and update them regularly. Managers can make teams short-term and long-term plans according to on different analyses. Training coaches watch, record and upload players physical and tactical data on players attribute database; research centre makes matching research according to players attribute data; major coaches choose ideal players to attend matches; training coaches change training plans for each player; medical department gives injure forecast and suggestion. Information systems also could help manage different levels of reserve/youth teams. With the evaluation of youth players attributes data and changing trends, the youth training centre would determine players moving between different levels. Youth players performance status will be analysed and sent to managers as a reference for a new contract making (Davila et al., 2007).

Football and the way that is played it is constantly changing. “Is a game of mistakes, whoever makes the fewest mistakes wins” (Cruyff, 2016). The game is becoming more tactical and less physical like was in the past. Coaches have more ways to apply their knowledge since technology is advancing and devices and Information Systems have been created to facilitate their job. At This Time, the best sporting results usually lie in the details that only can be spotted and notified by the use of technology tools, making the difference between the clubs that have it and do not have it. In the Big Data era, football is also incorporated. The amount of data that can be obtained and analysed from football is huge. That data creates competitive advantages to be used either in real-time during a competition or during practice, preparation, or recruitment.

As stated by Kellmann in 2010 competition is not only seen as the greatest form of training but also the pinnacle of testing and monitoring. With these new technologies, managers can have access to data and monitoring can help them with their choices.

By getting access to all this data football managers are starting to get to know about areas with more specifications than they ever can ask. Now it is possible to know everything about their players' conditions, physically and mentally, in which part of the pitch they are more valuable and many other things that can't be imagined. So, it looks to be important to know how to use this amount of data. However, it is still not being clear how football coaches use the available data and technology to improve the performance of their teams.

### **2.2.1. Types and Applications**

There are many types of IS for football that improve the sport and make easy the processes. Areas like tactics, health, performance, athletes' evaluation have IS involved. Football tactics are a very complex subject in football, any single aspect is important to change the course of the game (Almulla et al., 2020).

These new technologies have the possibility to show a large amount of data about any aspect of the game and even simulate some tactics. Health is an area of IS application. Injury prevention was taken to another level, since some studies have proven that with the use of some tracking devices it is possible to reduce injury risk, one of the departments that bring more debts to the football industry, since the assets of football clubs are in major part their players. Researchers realize that football players in European competitions miss on average 37 days in a 300-day season because of injuries, and 59% of injuries sustained were noncontact (Ehrmann et al., 2016). Injury rate notably results in reduced

player availability and consequent non-participation in match-play effects on team performance, even though contrary interpretations exist (Carling et al., 2015).

Football associations and investigators are attempting to improve the overall performance of the players, keep their health, and win more games. The performance of the players is being tracked by IS in official matches from local to international competitions, and into unofficial matches such as team's training sessions, training matches among team players, and friendly matches with other teams (Almulla et al., 2020).

### **2.2.2. Team Management Applications**

In professional Football, the constant pursuit to achieve success requires a regular collection, analysis and understanding of all the types of information collected basis on player performance in order to manage decision-making and produce feedback to prepare training and match strategies (C. Carling & M. Court, 2012). Football coaches are concerned with technical and health correlated performance metrics as cooperation are crucial when it comes to measuring the overall performance of the players (Almulla et al., 2020). The context of modern coaching processes is included in sports science and related to scientific principles to boost player availability and individual performance in training and competition (A. J. Strudwick, 2012).

### **2.2.3. Tactical and Performance Management Applications**

By measuring football players' performance through the use of a variety of technology, football coaches are assisted to take tactical decisions and keep their player's healthy and free of injuries. However, at the moment, regarding the relation between performance measuring technologies and the metrics they measure there is not much information. Through the monitorization of the performance of players in matches and training, football managers have the task of choosing the best players in each position much more simplified since it's possible to have access to information provided by the performance statistical data each player has produced, as their sprint speed, movement on the pitch or even if is everything fine with their health after a powerful training or a more physical match day (Almulla et al., 2020).

By using Key Performance Indicators (KPI) that are management tools to release the measure and consequently the level of performance and success of determined action, it is possible to rate passes, crosses, penalty area entries, set-plays, goal attempts and time spent in ball position. This tool has received general attention in particular concerning match outcomes and achieving success (Carling & Court, 2012).



## **2.3. COMPUTER-BASED TECHNOLOGIES FOR FOOTBALL**

Monitoring players' physical activity through matches and training is currently a frequent practice in professional football (Buchheit et al., 2014). To monitor the players' performance, football associations and investigators are applying distinct forms of tracing technologies that are capable of tracking different systems of measurement of the players. These technologies substitute the manual process where expert observers review taped videos of the matches and program players' activity patterns. These technologies help decrease the time required to gather data about the players during matches and assist coaches in assembling more data about different aspects of the players (Almulla et al., 2020).

To make possible that motorization Electronic Performance & Tracking Systems were created. In general terms, EPTS can be classified into environmental sensors (Rein & Memmert, 2016), third party datasets (STATSports, 2020) and optical devices (Trewin et al., 2017). More easily, they can be categorized as Local positioning systems (LPS), global position systems (GPS) and Optical-based camera systems. These Information Systems are used to improve player and team performance (FIFA, 2020). There are three forms of physical tracking devices available, they are Local positioning systems (LPS), GPS systems, Optical-based camera systems. All these systems are of interest to monitor players' activity in the field, and each has advantages and disadvantages (Buchheit et al., 2014).

Apart from Physical Tracking devices also there are Computational Technical Approaches. These devices are more recent in the history of football and are revolutionary. They are Artificial Intelligence (AI) and Virtual Reality (VR). With these new technologies, it's now possible to achieve new opportunities in football since these devices open a range of new ways to see and explore football (Ferrer et al., 2020).

### **2.3.1. Physical tracking devices**

#### **Global Positioning Systems (GPS)**

GPS technology is used to get the location or position relative to the field, through satellites. The data that is extracted from the device provides information to football clubs about their football players. The GPS allows analysing stats like total distance, top speed, power plays, sprint distance, load, and intensity (Ehrmann et al., 2016). With all of this data, players can be monotonized and the risk of injury can be prevented.

The use of GPS technology to evaluate players in training and the game has become predominant in professional football. In recent years, the interest in GPS using to have a balance between training stress and recovery has increased with the goal of maximize performance potential and minimize the risks of injury (Rossi et al., 2018). Injuries have a great impact on professional football since they have a considerable impact on recovering players and a large influence on team performance (Ehrmann et al., 2016). A recent study has concluded that players in European competitions miss on average 37 days in a 300-day season through injury. To prevent these injuries is important to monitor players by using GPS (Pons et al., 2019).

GPS technology has suffered an exponential growth in recent years for the quantification and management of external load in football training seasons and matches. This can be explained since in 2015 FIFA impose new rules that allow the use of GPS to monitor the performance and tracking players during competitive matches (Hoppe et al., 2018).

The main benefit of the GPS is the use of satellites which is an advantage to other systems since those can only be used on the football field where they have been previously installed. When it comes to limitations, the device has to be attached to the player and can be uncomfortable for match day usage and also there are some accuracy concerns of measured data. Still, this technology contributes with more precision relative to others and informational richness about external and internal load (FIFA, 2020; Pons et al., 2019).

### Local Positioning Systems (LPS)

Similarly, to GPS, the LPS technology provides information about the players location determining movement patterns in the team. However, LPS only works locally and just give the actual position in a presented local area. LPS works by using three or more short-range signalling beacons with a known exact location for positioning footballers through direct line-of-sight signalling technologies. By having a local sign antenna, LPS is allowed to operate at higher sampling rates, which enhances the validity and consistency for team sport detailed measures (Buchheit et al., 2014). One of the big advantages of this technology is that players don't need to wear any sort of gear (FIFA, 2020).

Studies about this technology have identified has main benefits the accuracy of measured data in real-time and the high number of measurements possible. Also, the ultra-wideband technology reduces the chances of interference in the transmission path. However, this technology has also some limitations since it required a fixed installation on the stadiums and in addition, the installation is very expensive and takes a long time to install (Meng et al., 2020).

### Optical-based camera Systems

Optical-based camera systems correspond to the monitorization of the user's position due to visual information. One or more fixed video cameras are placed in different angles in the same football game to capture players, and through a computer vision technique, it is possible to determine the position of each one, performing as electronic eyes (Meng et al., 2020).

This type of system captures physical and tactical information about the team. The physical information is obtained through a player recognition operation and tracking of the real-time location, which allows calculating the movement variables of each player and other physical data. The tactical information is acquired with the knowledge of the position of different football players and their interactions. Therefore, a great quantity of data is assembled, and it is possible to access a detailed analysis of the team through the game (Pappalardo et al., 2019).

Some of the aspects that can be analysed include spatial dimension, through the assessment of the position of each player, in which information about the spatial distribution of players and events, and players' behaviour is provided. Also, temporal information, in which by paying attention to when an event occurs it is possible to analyse the dynamics of the team such as the increase or decrease of attention due to a certain stimulus. Another aspect is team analysis, which can be acquired with the analysis of the interaction between players, and it is possible to select the most efficient tactical patterns across teams. Finally, player analysis, which can be done with a multi-dimensional evaluation,

allowing the comparison of the performance of players and track of the evolution of each one in time (FIFA, 2020)

Regarding this knowledge, studies have concluded the benefits of optical-based camera systems in football. They include the fact that it is non-invasive to players; it is frequently used in the football market and has a high sampling rate, ball tracking is possible. Also, there were notified some limitations such as the limited number of measurements, tracking occlusions require manual corrections and the installation time (FIFA, 2020).

### **2.3.2. Computational technical approaches**

#### **Artificial Intelligence (AI)**

Artificial intelligence (AI) refers to a large range of computer science instructed to build smart machines programmed to execute tasks that would usually involve human intelligence. Therefore, AI means the simulation of human intelligence, through the use of machines. Its goal includes learning, perception, and reasoning, and is being used in a variety of industries (Claudino et al., 2019).

Scientists started by designing an artificial neural network (ANN), which is a piece of computer system established to mimic the analyses and process of information of the human brain, and which learns based on inputs and outputs, creating patterns. This was the foundation and the steppingstone in the search for AI (Barron et al., 2018).

Through the use of this technique, it was possible to develop machines capable of classifying and predict events, allowing it's used to be applied to real-world problems. In team sports, ANN has started to be used as a technique of analysis of performance data, and as a method of performance prediction of professional football players (Barron et al., 2018).

Studies that assessed a vast number of variables in a large sample size, in the context of football, were able to find key factors linked with career progression, proving the valuable use of ANN in this industry. A specific study focused on the analysis of the performance of three groups, with different playing positions, to understand the key differences between players of different levels. An ANN was used in this study due to its accuracy in providing predictive methods. The study found indicators of a better career progression linked with variables such as international experience, defensive variables, passing variables, number of possessions and penalty area entries, thus proving the crucial objective tool aid in the industry of football (Barron et al., 2018).

AI also has application in the context of team sports, for injury risk assessment. To analyse the probability of the occurrence of having an injury two different tools can be used: decision tree classifier (DTC) and support vector machine (SVM). A DTC corresponds to a decision support device that uses a tree-structure model of choices and their possible outcomes, supply costs and efficiency. A decision tree is created as a predictive model to go through observations about an item to reach conclusions. SVM is a concept in computer science that analyses data and recognize patterns, used for classification and regression analysis. For each input, it predicts which of two possible classes the input is part of, therefore labelling data (Claudino et al., 2019).

The combination of the two technologies, DTC and SVM, has been used in the context of sports, specifically in football and studies proved that combining SVM and DTC provides a hybrid approach, which results in a more accurate and efficient hybrid classifier. This resulted in the prediction of injuries of football players and allowed the optimization of the team's performance (Capobianco et al., 2019; Claudino et al., 2019).

Success in a team sport, from the point of view of sports science and medicine staff, is to use knowledge based on evidence in an effective manner, to develop a decision-making process for performance optimization. The advance of these artificial intelligence technologies, for instance, the ANN, DTC and SVM, can fill some breaches left by traditional statistical methods, gathering a large quantity of information, and analyse it through optimized algorithms to produce better results for supporting decisions and provide applied knowledge to sports professionals (Capobianco et al., 2019).

### Virtual Reality (VR)

In the game of football, every aspect counts since it is a very complex game. From the body language to the environment, every single detail can induce a different outcome and therefore change the whole course of the game. Virtual Reality (VR) can mimic the environment of the game and allow each player to improve his performance by processing speeds, graphics, and motion tracking, in a specific moment of the game (Dessing & Craig, 2010).

VR mentions a computer-generated recreation in which an individual can relate with an artificial three-dimensional atmosphere, letting the user feel absorbed in their surroundings. The environment is perceived through electronic devices such as special goggles with a screen, gloves fitted with sensors, virtual reality headsets or helmets (Dessing & Craig, 2010).

This technology can be adapted to the science of football, interfering with behavioural neuroscience. Through the use of immersive, interactive VR that allows the natural body and hand movements, players are able to practise specific moments of the game such as free-kicks or any dead ball situations, and goalkeeping (Dessing & Craig, 2010).

A lot of studies suggest that virtual reality has a significant value in understanding the optical variables that are important in guiding action (Ferrer et al., 2020) A specific study focused on the use of VR technology to examine a highly dynamic sports scenario. It aimed to study the goalkeeper's behaviour, through the use of VR able to reproduce the same ball trajectory across trials. It was found that goalkeepers do not take spin-induced lateral ball acceleration into account when stopping free-kicks, resulting in movement biases, which showed that they are influenced by the limited sensitivity to visual acceleration. Therefore, the use of training through VR can allow a goalkeeper to better his performance by training the visual ball trajectory (Dessing & Craig, 2010).

Another study made an experiment that involved football players with different experience levels. This experiment aimed to validate the capacity of VR systems to measure the read-the-game ability of football players and the sense of presence provided to the user. The VR was able to access kinetic body tracking and passing gesture recognition and translate it to a football in-game situation provided by FIFA. The study validated the capacity of the system to measure the visual component of read-the-game and concluded that its prolonged use allows football players and coaches to analyse, train and develop skills required to enhance the performance (Ferrer et al., 2020).

## 2.4. CASE STUDY “BARÇA INNOVATION HUB”

In Spain, Futbol Club Barcelona has created a sports centre for innovation, “Barça Innovation Hub” (BIH) where more than 2000 athletes, male, and female teams of 5 professional sports are studied in order to promote knowledge in the sports world and establish an ecosystem to collaborate on a global scale with universities, research centres, hospitals, leading brands, start-ups, and other sport entities. One of the biggest achievements of BIH was the “new tracking systems that redefine the word accuracy”. BIH abord themes like: “Monitoring technologies for sports analysis”, “how to improve data and decision-making using statistical analysis in football” or even “creating reports for coaches for better decision making” (BIHub Team, 2021).

Regarding the monitorization technologies used to analyse sports, allows clubs to understand the athlete’s current physical form, physical activity, and playing style, as well as exhaustion or their capability throughout training sessions or matches. Due to all kinds of sensors and cameras that broadcast real-time information of players position, speed, heart rate data, all this is achievable. This data also can be considered to evaluate trends or potential improvements to use in the game. One example of this was a new camera FCB start to use in their academy (BIHub Team, 2021).

### 2.4.1. Pixellot Air

Created and designed by Pixellot with cooperation with Barça Innovation, this new camera named Pixellot Air can monitor and record matches in any facility. Barcelona on their academy with this new camera technology can now have access to a new way to get even more information with precision and comprehensively monitor their teams’ sporting activities. This new portable camera record automatically games and training sessions gathering detailed technical data and information about the activity, which can be used at any football ground or sports. At the moment, Futbol Club Barcelona has implemented these cameras at the Ciutat Esportiva Joan Gamper training and inside Estadi Johan Cruyff. The objective is to record all activities and use AI to track different game situations based on players actions and therefore analysed by club analysts that put together highlights (BIHub Team, 2021).

This new camera consists of a device that can record more than 12 hours of play and performs automatically with no need for a camera operative, power, or internet connection. The video recorded by the camera incorporates instant coding and tagging to get match data and heat maps similar to the installed cameras on the Ciutat Esportiva and Estadi Johan Cruyff. The camera will be accessible for the 44 Barça Academies around the world to record all of their sporting activities and the complete analyses will be useful for evaluating how the Barça methodology is being employed (BIHub Team, 2021).



Figure 1- Camera Pixellot Air

#### 2.4.2. Pixelott AI technology

In order to record training sessions and training automatically a new system developed in partnership with Pixellot and BUHUB was developed. Through the use of AI will simulate a camera operative of a high-quality panoramic view of the field. This panoramic image is possible due to the use of a wide-angle camera or multiple wide-angles cameras that therefore the images are put together (BIHub Team, 2020a).

This technology operates with sophisticated auto-tracking algorithms to follow the flow of play with high-resolution panoramic images. To allow precise human-like capture these AI decisions need to be made with minimal latency to permit precise human-like capturing. The latency buffer is essential since is like *“a camera operator who looks into the future”* to comprehend the flow of the play and then generates a conscious decision about how to film it (BIHub Team, 2020a).

With the aim to provide the right viewing experience this technology must simulate the camera operator capture, recreating the smooth movements, preferably simulating the movement of a video tripod with a fluid head (BIHub Team, 2020a).

Since the game must be in a different way for football fans and for the coaching staff the automation has to prove its efficiency. In the field of what is more important for the coaching staff, it included the tactical view of the game, team formation, all the field players excluding goalkeepers and for the fans, the aim is simply a good angle to enjoy the game the best way possible (BIHub Team, 2020a).

The automatic capture technology englobes two of the following standards, automatic ball detection and player(s) detection. Automatic ball detection is based on the algorithm that tries to identify and stick to the ball. Player detection allows a better insight into the action and serves as a basis for game state detection. Together these technologies are based on the capability to analyse the images and differentiate between the background and the objects of importance namely the ball and player(s). When players stand still for a few seconds it is one of the challenges to detecting them, when this happens the algorithm must ensure that the player is not confused with the background. This is very important since in football when there is a free kick or penalty sometimes players standstill for an interval of 30 seconds. Because of that, the algorithm must be able to differentiate the players that are active and in movement from the players that are not active, even when the active players are positioned far away from the ball. In addition, should be able to identify the referee (BIHub Team, 2020a).

Based on player and ball detection the game state must be identified by the algorithm. The game state stands for the type of play currently happening. In football, a penalty kick, corner kick, free kick or free throw are examples of a game state. In each example there are certain padrones, they are all different, so the algorithm must be able to predict these padrones to make smarter decisions about the best way to capture the action. Deep learning algorithms are the solution to overcome this challenge. They can learn how to identify the game states automatically centred on data set examples. The system detects the characteristics of each one of the game states to classify each one specifically, and by considering all the parameters the system can decide the best way to capture each frame (BIHub Team, 2020a).

### 2.4.1. WIMU PRO

Another example of tracking technology implemented by FCB was the WIMU PRO. FC Barcelona was the pioneering team to adopt this system. In the year 2015, the way Data Analytics could transform sport was analysed and certain tech magazines start to become interested. To achieve that transformation some specialists, notice that that Data Analytics would be a key to gather data and launch it on an analysis platform. This starts to become possible with the combination of the use of EPTS and software which gather data (BIHub Team, 2020b).

In the first year of the collaboration between FCB and WIMU PRO, the main focus was to improve the equipment itself. To improve it, every week, 25 FCB coaches took a workshop given by the collaboration to discuss this device's metrics, reliability, and ease of use. After that Key Performance Indicators (KPI) reports for RealTrack were generated to analyse the best performance variables to apply these changes and improvements to technology, design as well to adjust the technology always aiming to achieve the best results, making its measurements more useful to coaches and trainers (BIHub Team, 2020b).

The fact that WIMU PRO has hybrid data transmission technology, a dual system that uses GPS and ultra-wideband (UWB) radiofrequency was one of the features that appeal FC Barca to extend this technology to five sports areas because this feature minimizes errors due to data loss and permits the device to be used only through UWB for indoors when there is no satellite coverage (BIHub Team, 2020b).

Since team sports need different configurations, an additional application was created by the name of SVIVO for the football team. This application is destined to monitor the live-work weight during training and the coaches can customize the measurements they consider more important during the session. This application's very helpful to adapt to specific situations. For example, if a player is recovering from an injury or returning from holidays it's easier to adapt to the exercises (BIHub Team, 2020b).



Figure 2- WIMU PRO

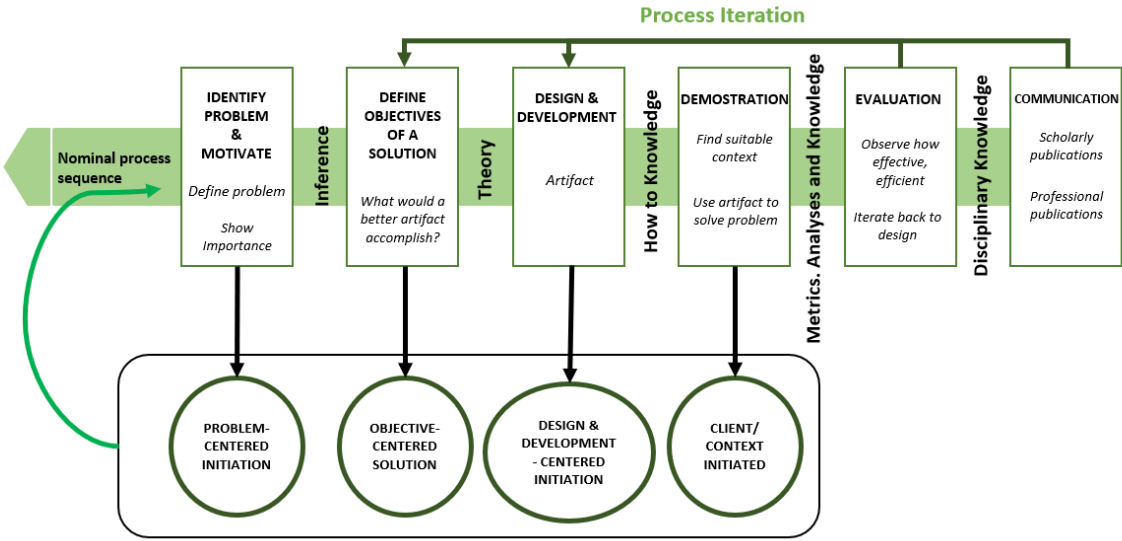
### 3. METHODOLOGY

This chapter approaches the *Design Science Research* that was utilized in the realization of this thesis relating it with the strategy of investigation adopted.

#### 3.1. DESIGN SCIENCE RESEARCH

This thesis is based on *Design Science Research*. However, reveals some differences in the definition proposed for the Design science research (DSR). The DSR involves an alternative to natural science. In DSR the researcher “creates and evaluates IT artefacts intended to solve identified organizational problems”(Hevner, 2004). The DSR is important to the IS community since focus on the position of IT artefact in IS research (Orlikowski & Iacono, 2001) and the low degree of professional significance of several IS studies.

The DSR process involves the following phases: first, the awareness of a problem, where the problem or challenge to be addressed is identified. Then the suggestion, where the objective for the solution is identified. Followed by the Development of the artefact. After is the Evaluation where the artefact is evaluated and tested in the requirements planned for validation. Lastly, it is in the reflection phase that the artefact is updated, and the outcomes are reviewed and discussed. If in this phase, the conclusion is not reached the proposed solution was insufficient to resolve the problem and a new cycle begins (Hevner, 2004).



(Ken Peffers et al., 2006)

Figure 3- Design Science Research model – adapted from (Peffers, 2006)



### 3.2. THE STRATEGY OF THE RESEARCH

The objective of this methodology is to build an Application Toolbox architecture for Football Coaches. The Design science research is therefore an appropriate methodology for this report since to validate what is proposed implementation is not mandatory and other methods can be used to evaluate the proposals made. The research will be organized into three steps as follows:

In the Problem awareness, to understand what kind of information is required by football coaches, identifying what type of data (health data, performance data or statistic data) is more important to improve the performance of their teams a literature review was made.

In the second phase, the Suggestion, define Objectives is important to understand which Information System can simplify some processes to facilitate the coaching job and enable him to get more out of the training.

The third phase, the Design and development, with the creation of an Application Toolbox architecture for Football Coaches.

The fourth phase, the Demonstration, by showing the Application Toolbox in a specific context where it can solve a problem.

The fifth phase, the Evaluation, by doing interviews with professional football coaches of Portuguese leagues that don't use Information Systems to understand if the Application Toolbox architecture will contribute to improving the performance of their teams.

Finally, on Communication, coaches needs and what kind of Information Systems are useful to the teams and to facilitate processes to achieve success are published.

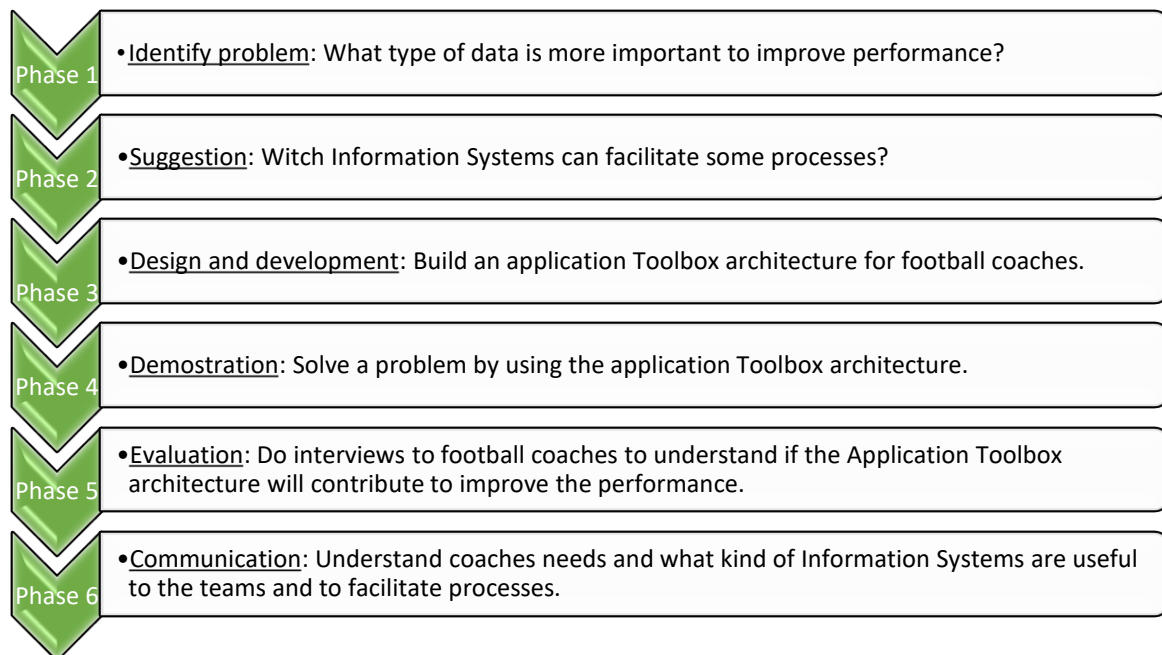


Figure 4- Methodology diagram

## 4. SOFTWARE TOOLBOX ARCHITECTURE FOR FOOTBALL COACHES

This chapter introduces a software toolbox architecture to help football coaches select technologies and systems to improve the performance of their teams. In this way, the assumptions that served base to the elaboration of the artefact, proceeding to its evaluation and discussion.

### 4.1. ASSUMPTIONS

Based on what was studied in the literature review about Football history and evolution, the new technologies introduced, coaches, their roles and how they related to these new technologies is possible to state the following:

- Football has an enormous impact on human life. Furthermore, football is at the top of team sports at the professional level. FIFA is composed of more member countries than the UN (Stein et al., 2016); (World's Most Popular Sports, 2010);
- Football is in constant change and development. Over the years the resources that teams have access to achieve success changed, with IS having a crucial role in that process. At the moment, the best sporting results are pendent from details that can only be spotted by the use of technology tools. In Big data era football is also incorporated (Rein & Memmert, 2016);(STATSports, 2020);(Buchheit et al., 2014);
- In the football coaching field, many areas can be improved through the use of IS technologies, like health, tactic, training, and performance. The constant pursuit to achieve success requires a regular collection and analysis of data and Information systems create players information database and update it regularly. Nowadays football coaches have access to much information about their team and players. That information is important to manage decision-making and produce feedback to prepare match and game strategies (C. Carling & M. Court, 2012);(Jovanovic et al., 2011);(Brink et al., 2010);
- Football coaches perform a very important role on their team to increase performance and the field of performance is traduced if football teams achieve or do not achieve success. The way coaches interact and communicate can influence football players positively or negatively. The leadership football coaches demonstrate is very important. Leadership is defined as “the behavioural process of influencing individuals and groups towards set goals” and make part of the coaches' roles. Qualitative studies have argued in advance of the importance of leaders for performance (Kattuman et al., 2019);(Brink et al., 2010);
- The physical performance of the player is determined using both wearable and in-field technologies. By the understanding of the relationship between technology and performance as well as how and where it is being applied helps in enhancing the supervising process, which leads to increasing the global performance of the players (Almulla et al., 2020);(Carling et al., 2015);

- Monitoring players' physical activity through matches and training is currently a frequent practice in professional football. To monitor the players' performance, football associations and investigators are applying distinct forms of tracing technologies that are capable of tracking different systems of measurement of the players. These technologies substitute the manual process where expert observers review taped videos of the matches and program players' activity patterns. These technologies help decrease the time required to gather data about the players during matches and assist coaches in assembling more data about different aspects of the players (Almulla et al., 2020); (Buchheit et al., 2014); (Rein & Memmert, 2016);
- There are three forms of physical tracking devices available, they are Local positioning systems (LPS), GPS systems, Optical-based camera systems. All these systems are of interest to monitor players' activity in the field, and each has advantages and disadvantages (Buchheit et al., 2014);(Pons et al., 2019); (Hoppe et al., 2018);
- Apart from Physical Tracking devices also there are Computational Technical Approaches. These devices are more recent in the history of football and are revolutionary. They are, Artificial Intelligence (AI) and Virtual Reality (VR) (Ferrer et al., 2020);
- Artificial Intelligence can be used to predict injuries and analyse players and teams' data in detail. Through the use of this technique, it was possible to develop machines capable of classifying and predict events, allowing it's used to be applied to real-world problems. In team sports, has started to be used as a technique of analysis of performance data, and as a method of performance prediction of professional football players (Barron et al., 2018);(Claudino et al., 2019);
- Virtual Reality allows football players to improve performance by processing speeds, graphics, and motion tracking in a specific moment of the game. Can mimic the environment of the game. Currently is used for body tracking (Dessing & Craig, 2010);(Ferrer et al., 2020).

## 4.2. TOOLBOX

The assumptions made in the previous section led to the creation of an application Toolbox architecture for football coaches to facilitate processes. This toolbox has the objective to improve the relationship between IS, the football coach, and their team. It will enable the coaches to interact more with some aspects of this team, making their work more dynamic than already is, with a final objective of improving the performance of their teams. Figure 5- Toolbox architecture represents the main components of the developed artefact.

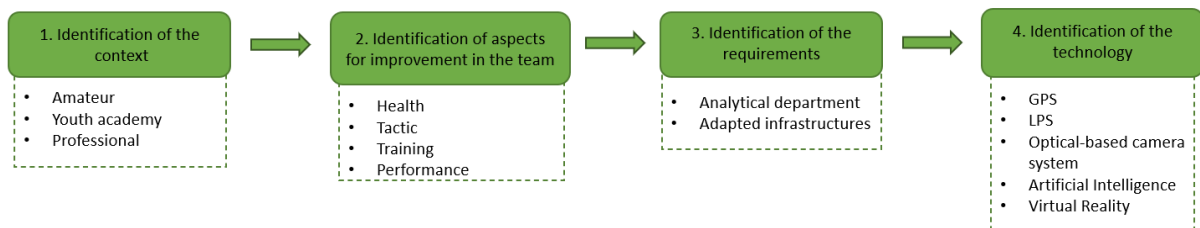


Figure 5- Toolbox architecture

### 4.2.1. Identification of the context

The first step of the application Toolbox architecture is the identification of the context. Managers must select which one is the context of their team. They can choose between amateur, youth academy or professional level. Finally, after submitting all this information can pass to the identification of the aspects for improvement in the team.



Figure 6- Flowchart for Identification of the context

#### 4.2.2. Identification of aspects for team improvement

The second step of the application Toolbox architecture is the survey of all existing aspects in the team that the football coach understand must be improved. These aspects vary by what the coach identify as a “weakness” of his team. Managers can identify if there are aspects to improve in health, tactic, training, and performance. Then those aspects must be evaluated. After evaluation must advance to the Identification of the requirements.

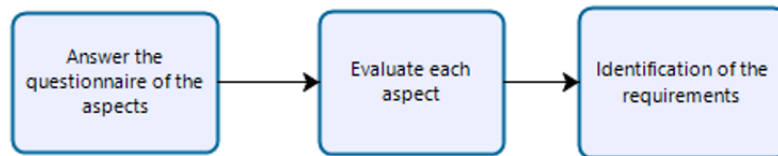


Figure 7- Flowchart for Identification aspects for team improvement

The aspects are levelled in “+”, “+ +” and “+ + +” depending on if the aspect is less (“+”) or more (“+ + +”) developed. Managers should evaluate the state of the situation of their teams with those three options of plus signals. The tables below represent each aspect, his level and what the aspect consist of. In general, the levels consist in:

- “+” – the aspect is not developed with technology or if it is the technology as less influence or no influence at all. Must be selected if the team don’t use technology at all or if the team use technology those technologies have just a few or no influences on helping the team.
- “+ +” – the aspect is developed with technology that has an influence on helping the team and in some cases is controlled by a specialist. Must be selected if the team already use technology but there are more things to improve.
- “+ + +”- the aspect is developed with technology and could have an analytical department and in some cases also AI assistance and the influences on helping the team are noticeable. Must be selected if the aspect is not a meaningful aspect to improve since is already technology explored and the results showed are satisfying the needs.

Table 1- Health aspects has the Health aspects are divided into two areas, injury prevention and physical capability. These two areas are therefore categorized by level.

- “Health +” – the football club don’t have technology in his health centre or if it has it's not technologically advanced and the improvements are not notable.
- “Health + +” – the football club have technology in his health centre. This technology is helping the team improve but some aspects have room for progress.
- “Health + + +”- the football club have technology in his health centre. This technology is helping the team improve a lot and there is room to progress but not in a meaningful way.

Health	+	++	+++
Injury prevention	Local	Computer-assisted/Specialist	AI Computer-assisted
Physical Capability	Local	Computer-assisted/Specialist	AI Computer-assisted

Table 1- Health aspects

Table 2- Tactic aspects has the Tactic aspect of the team analysis. This aspect is therefore categorized by level. The levels consist in:

- “Tactic +” – the football club don’t have the technology to improve tactics or if it has it's not technologically advanced and the improvements are not notable.
- “Tactic + +” – the football club have the technology to improve tactics. This technology is helping the team improve but some aspects have room for progress.
- “Tactic + + +”- the football club have the technology to improve tactics. This technology is helping the team improve a lot and there is room to progress but not in a meaningful way.

Tactic	+	++	+++
Team analysis	Local	Computer-assisted/Specialist	AI Computer-assisted

Table 2- Tactic aspects

Table 3- Training aspect has the Training aspect of the team analysis. This aspect is therefore categorized by level. The levels consist in:

- “Training +” – the football club don’t have technology in his training centre or if it has it's not technologically advanced and the improvements are not notable.
- “Training + +” – the football club have technology in his training centre. This technology is helping the team improve but some aspects have room for progress.
- “Training + + +”- the football club have technology in his training centre. This technology is helping the team improve a lot and there is room to progress but not in a meaningful way.

Training	+	++	+++
Team analysis	Local	Computer-assisted/ Specialist	AI Computer-assisted/VR

Table 3- Training aspect

Table 4- Performance aspects has the Performance aspect of the team analysis. This aspect is therefore categorized by level. The levels consist in:

- “Performance +” – the football club don’t have the technology to improve performance or if it has it's not technologically advanced and the improvements are not notable.
- “Performance + +” – the football club have the technology to improve performance. This technology is helping the team improve but some aspects have room for progress.
- “Performance + + +” – the football club has the technology to improve performance. This technology is helping the team improve a lot and there is room to progress but not in a meaningful way.

Performance	+	++	+++
Team analysis	Local	Computer-assisted/ Specialist	AI Computer-assisted/VR

Table 4- Performance aspects

### 4.2.3. Identification of the requirements

After a pass through all the processes of identification of the context and identification of aspects to improve, the requirements must be presented. To use the toolbox architecture, football coaches must have access to some resources. Technologies like Virtual Reality require a specific condition, like indoor pitches with sensors all over the field to restrict the virtual reality pitch to the limits of the real pitch. LPS and optical-based camera systems require conditions to install the antenna and cameras respectively, GPS systems require the equipment for each payer to track them and artificial intelligence requires adapted software to gather information. However, some of these technologies can be adopted via outsourcing, by contracting specialists to gather the information and analyse it. Because of all the requirements, to filter the technologies that can be used to help coaches in their decisions the requirements will take into consideration the context of the team. After identifying which requirements, the application toolbox is ready to proceed to the identification of the technology.

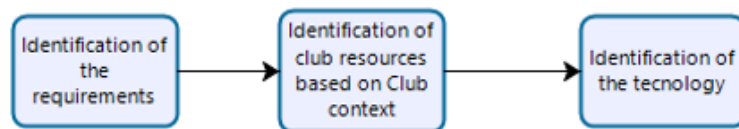


Figure 8- Flowchart for Identification of the requirements

To identify the requirements the aspects must be framed taking into account the context. The table below is important to understand the status of the team and where it is positioned.

	Aspect/Context		
	Profissional	Youth academy	Amateur
Health	+++	+	++
Tactic	+++	++	++
Training	+++	++	++
Performance	+++	+	+

Table 5- Requirements per context for each aspect



#### 4.2.4. Identification of the technology

Finally, the identification of the technology. After the identification of requirements and considering the context, the application Toolbox will choose if it is GPS, LPS, Optical-based camera view, AI, or Virtual intelligence the technology and the artefact proceeds to the final results. By achieving this step, the football coach will know which technology can fulfil the pretended requirements and is one step ahead in the process of achieving success with his team.

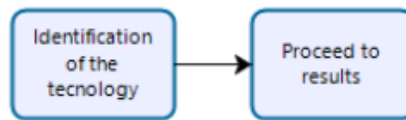


Figure 9- Flowchart for Identification of the technology

These technologies based on the context can have different utilities and can be divided into Physical tracking devices and Computational tracking devices. Physical tracking devices are represented in the table below:

Physical tracking devices		Health		Tactic	Training	Performance
	Sub-areas	Injuries Prevention	Physical Capabilities			
Global Positioning Systems (GPS)		a)	b)	c)	d)	e)
Local Positioning Systems (LPS)		f)	g)	h)	i)	j)
Optical-based Camera Systems		k)	l)	m)	n)	o)

Table 6- Physical Tracking Devices

#### 4.2.5. Physical Tracking Devices:

- a) GPS device implemented in a vest record all player movements and can predict in what type of movements the player can injure themselves. The GPS can monitor the live workload and with that data, coaches can adapt exercises to prevent injuries. This is often used when a player is recovering from an injury or when players return from holidays.
- b) The GPS device assembles information from the football player and analyses their physical capability. Distance covered, sprint distance, sprints completed, and sprint distance is analysed. This data help coaches to understand in which areas the player can improve and adapt exercises to achieve that improvement.

- c) GPS show the player position on the field in all moments of the game. Football coaches can see the game from another perspective. Where their players occupy more space, the areas they are supposed to cover and don't cover and based on those information change tactics and dynamics.
- d) The device helps football coaches to gather information from data to make decisions. The information collected is analyzed, by coaches and technical staff to check improvements during training sessions, like if plyers are more and more physically prepared, to identify the ones that are doing well, by analyzing information that was not possible to notify just by observing players during training.
- e) GPS devices by collecting all data about players, the sum of all indicators can translate the performance of the player. By evaluating the information provided players performance can be classified as above average or below average.
- f) LPS technology by precisely localize players in the field, the distances covered help to control if players are lowering their physical performance on training and matches and track them to prevent injuries.
- g) LPS technology, like GPS, can localize players infield, although, LPS has more precision since uses signal beacon instead of satellites like was referred to before. Subsequently, with more precision, the data gathered about players positions can be traduced precisely in information about the physical capability of the players. If they cover more areas or less, then the coaches were expected.
- h) Like GPS, LPS show the player position on the field in all moments of the game however with more precision. Football coaches can see the game from another perspective. Where their players occupy more space, the areas they are supposed to cover and don't cover and based on those information change tactics and dynamics.
- i) The device helps football coaches to gather information from data to make decisions. The information collected is analyzed, by coaches and technical staff to check improvements during training sessions, like if plyers are more and more physically prepared, to identify the ones that are doing well, by analyzing information that was not possible to notify just by observing players during training.
- j) LPS devices by collecting all data about players and evaluating the information, players performance can be classified as above average or below average.
- k) Based on the physical information, the movements of each player, it is possible to compare training and matches and evaluate the levels of intensity to prevent injuries.

- l) The physical information is obtained through a player recognition operation and tracking of the real-time location, which allows calculating the movement variables of each player and other physical data.
- m) The tactical information is acquired with the knowledge of the position of different football players and their interactions. Another aspect is team analysis, which can be acquired with the analysis of the interaction between players, and it is possible to select the most efficient tactical patterns across teams.
- n) The optical-based camera systems automatically record games and training sessions gathering detailed technical data and information about the activity, which can be used at any football ground.
- o) With player analysis, which can be done with a multi-dimensional evaluation, allowing the comparison of the performance of players and track of the evolution of each one in time.

Computational technical approaches are represented in the table below:

Computational technical approaches		Health		Tactic	Training	Performance
	Sub-areas	Injuries Prevention	Physical Capabilities			
Artificial Intelligence (AI)		p)	q)	r)	s)	t)
Virtual Reality (VR)		u)	v)	w)	x)	y)

Table 7- Computational technical approaches

#### 4.2.6. Computational technical approaches

- p) Artificial Intelligence can help predict injuries. Based on players attitudes during training and games, AI can predict if they keep doing certain movements and workloads predict if they are prone to injury or not.
- q) Physical capabilities can be monitored by the AI to maintain the parameters required at a specific moment of the season, after and before matches.

- r) Artificial Intelligence in the tactic department can be used to predict patterned movements of other teams.
- s) Predict player movements, spot patterns and indicates what should players do next.
- t) AI help players improve performance by examining players last performances and identifies some patterns and issues that occur in order to improve future performances.
- u) Virtual Reality allows football players to improve performance by processing speeds, graphics, and motion tracking in a specific moment of the game. Also, VR provides a unique opportunity of training without workload, a perfect option for recent injury players.
- v) Virtual Reality is able to mimic the environment of the game. Currently is used for body tracking.
- w) In the tactic area, VR can help players decide better on the field and understand their position, where should they defend or attack.
- x) VR creates a new department in training where the analysts work on scenarios to train some important situations to prepare players for “everything”. With VR the decision making is the principal category to train. Scenarios, where the player must decide to each player, must pass are evaluated with good, medium, or bad decision and a report it is given to the couch.
- y) VR technology can access the Kinetic body tracking and passing gesture and translate it to an in-game situation. By practising before games, the in-game situations players improve their performances even it's not those realities that prepare players for many scenarios. The capacity of the system to measure the visual component of read-the-game and concluded that its prolonged use allows football players and coaches to analyse, train and develop skills required to enhance the performance

To advance to the identification of the technology there are some processes to pass through. Followed what was stated before based on what is answered on the evaluation questionnaires the status of the team for each aspect taking into consideration the context is classified as:

- Red – Must apply improvements
- Yellow- Should take into consideration
- Green- The improvements are not meaningful

Also, each technical option is identified by a char as presented before in Table 6- Physical Tracking Devices and Table 7- Computational technical approaches, to identify the technology.

Aspects		Context								
		Professional			Youth academy			Amateur		
Level		+	++	+++	+	++	+++	+	++	+++
Health		a,b,f,g,k,l,p,q,u,v	p,q,u,v		b,g,l			a,b,f,g,k,l		
Tactic		c,h,m,r,w	r,w		c,h,m	c,m,r		c,h,m		
Training		d,i,n,s,x	s,x		d,i,n	d,n,s		d,i,n		
Performance		e,j,o,t,y	t,y		e,j,o			a,b,f,g,k,l		

Table 8- Evaluation table

Then, the technology is classified as Red, Yellow and Green established on how often is used based on the context as can be seen below:

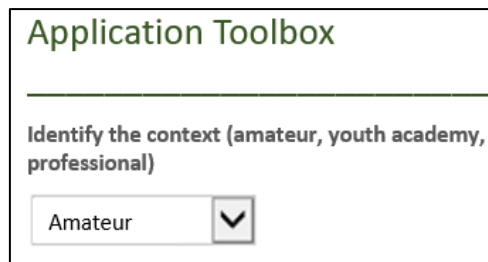
- Red – Rarely used
- Yellow- Sometimes used
- Green- Often used

	Technology/Context		
	Professional	Youth academy	Amateur
Global Positioning Systems (GPS)			
Local Positioning Systems (LPS)			
Optical-based Camera Systems			
Artificial Intelligence (AI)			
Virtual Reality (VR)			

Table 9- Context and Technology relation

### 4.3. DEMONSTRATION

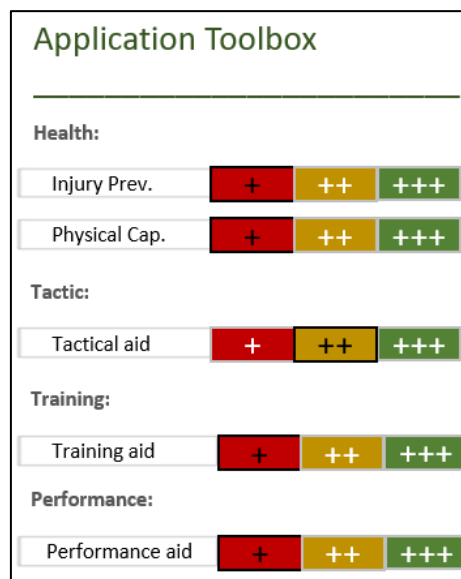
For the season of 2021/22, the university football team “Football Club IMS”, which belongs to NOVA IMS, want to increase the performance of their senior team players. In the past season players have suffered a lot from injuries and this season, the objective is to reduce the number of injuries that last year difficult a lot the season. Also, the football manager during the season identifies that training sometimes does not work as he expected and fills that need more information about his players. Because of these “problems” the club use the Application Toolbox to understand what they must do to achieve their goals. First, they start to identify the context, that in this case, it is Amateur.



The screenshot shows a web interface titled "Application Toolbox". Below the title is a horizontal line. Underneath, the text reads "Identify the context (amateur, youth academy, professional)". Below this text is a dropdown menu with "Amateur" selected and a downward arrow icon.

Figure 10- Application Toolbox Context selection

Then coaches start to evaluate the aspects by answering the survey with the plus (“+”) signs. With a “+”, the aspect is not developed with technology or if it is the technology as less influence or no influence at all, with “+ +”, the aspect is developed with technology that has an influence on helping the team and in some cases is controlled by a specialist, and with “+ + +” the aspect is developed with technology and could have an analytical department and in some cases also AI assistance and the influences on helping the team are noticeable. The coach answers were as follows:



The screenshot shows the "Application Toolbox" interface with evaluation results. It is divided into four categories: Health, Tactic, Training, and Performance. Each category has a list of aspects with corresponding evaluation ratings represented by colored boxes containing plus signs.

Category	Aspect	Rating
Health:	Injury Prev.	+
	Physical Cap.	++
Tactic:	Tactical aid	++
Training:	Training aid	++
Performance:	Performance aid	++

Figure 11- Application Toolbox Aspects evaluation

On the Application Toolbox, the football manager selects his evaluation based on the team. The application toolbox concludes that two aspects can be improved based on what was programmed, as shown below, Health and Training should be both on “++” and the coach evaluate them both as “+”.

Aspect	Amateur
Health	++
Tactic	++
Training	++
Performance	+

Table 10- Context and Aspect relation

After identifying those aspects that need improvement, the Application Toolbox will cross the information with the technologies. So “Amateur”, “Health” and “Training” will enter the system and is generated what technologies can be chosen to solve this problem. The Toolbox identifies the technologies to improve Health and training, they were GPS, LPS and Optical based camera systems.

Physical tracking devices		Health		Training
	Sub-areas	Injuries Prevention	Physical Capabilities	
Global Positioning Systems (GPS)	a)	b)	d)	
Local Positioning Systems (LPS)	f)	g)	j)	
Optical-based Camera Systems	k)	l)	n)	

Aspect	Amateur		
	+	++	+++
Health	a,b,f,g,k,l		
Training	d,i,n		

Table 11- Choice of Technology

Then these technologies pass to a process to identify their relationship with the context presented. The table below is represented the context and technology relationship. Green means that these technologies are often used in the context, yellow that are sometimes used and red that are rarely used.

Technology	Amateur
Global Positioning Systems (GPS)	Green
Local Positioning Systems (LPS)	Yellow
Optical-based Camera Systems	Green
Artificial Intelligence (AI)	Red
Virtual Reality (VR)	Red

Table 12- Context and Technology relation

Crossing the information in Table 12- Context and Technology relation and Table 11- Choice of Technology the Application Toolbox concludes that the right technology is the GPS and Optical-based Camera System as the first option and LPS as the second option since LPS is represented as Yellow on the context relation table and GPS and Optical-based Camera System as green.

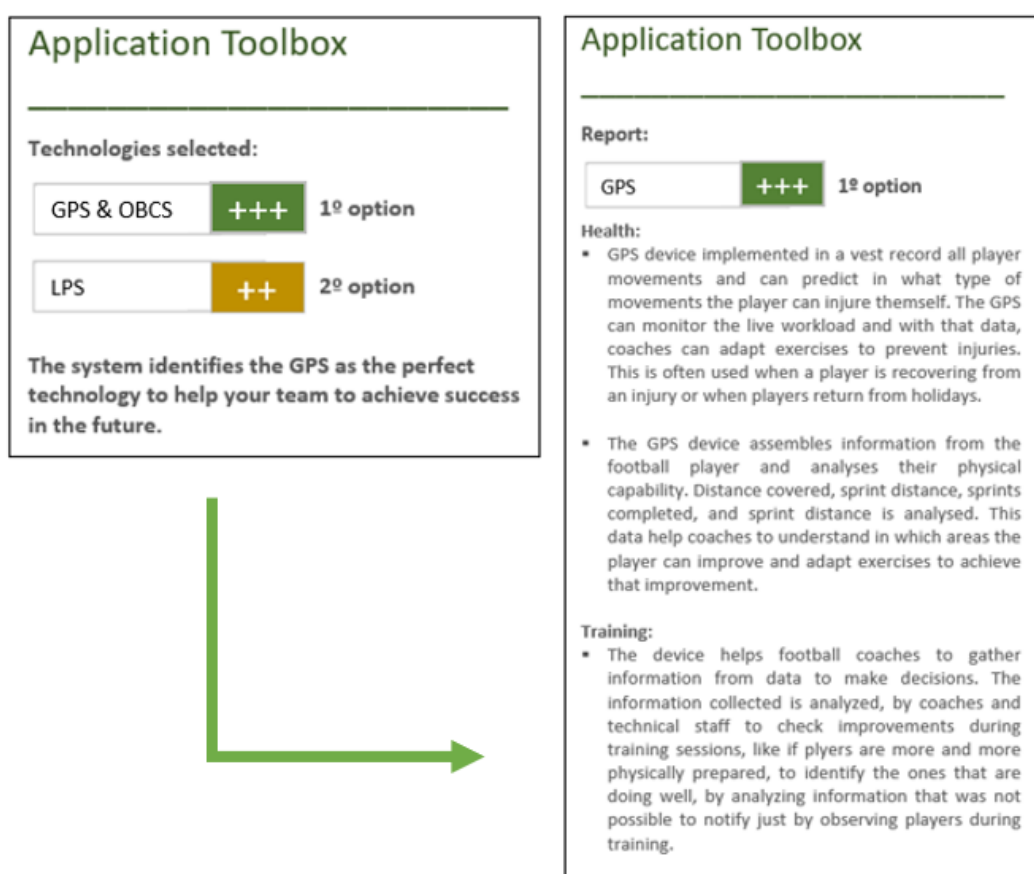


Figure 12- Application Toolbox final reports



The report concludes by indicating the GPS and Optical-based Camera Systems as the right technologies for the “weaknesses” presented by the football coach. In Figure 12- Application Toolbox final reports is presented the final report where is explained the reasons to choose the technology, since “Health” was presented as a high priority, GPS is the best device to prevent the injuries that occur last season. The GPS monitor the live workload and coaches can adapt exercises to prevent injuries using that data. Also is frequently used when a player is recovering from an injury or when players return from holidays. For “Training” the GPS device is indicated for player tracking, check improvements during training sessions, gathering information that was not possible to get just by watching players.

#### **4.4. VALIDATION**

Validation was carried by scheduling individual interviews with three football coaches, with experience in coaching and with different backgrounds and at different times of career. They were:

**Coach Sandro Jesus (SJ)** – first coach of under 15 team and assistance coach of under 17 team at Clube de Futebol “Os Belenenses” (CFB). A 26-year-old UEFA B coach level, with experience on the youth teams. In the past four years managed the under 13 teams on his previous club Atlético Clube do Tojal (ACT) for one year and on his actual club Clube de Futebol “Os Belenenses” (CBF) in the past three years managed under 13, 15, 19, coaching seven-a-side and eleven-a-side football. His objective is to understand his profile as a manager between the youth academy and high competition, he wants to experience the two and then eventually choose but he doesn’t close the door for new experiences since he wants to understand the game and all the steps that pass threw in all moments.

**Coach João Paulo (JP)** – first coach of under 17 team at Atlético Clube do Tojal (ACT). A 52-year-old UEFA C coach level, coaching teams since 1991, with experience on the youth teams starting in 2001/2002. Coached previously on Clube de Futebol “Os Belenenses” (CBF), Geração Benfica Escolas de Futebol, AC Milan Lisboa and on the last eight years managed under 11,13, 15 and 17 at Atlético Clube do Tojal (ACT), his actual club. Football is not his profession it’s a hobby that he takes very seriously since his profession is in the banking area.

**Coach Paulo Nunes (PN)** – technical coordinator at Grupo Sportivo Loures (GSL). A 50-year-old UEFA PRO coach, coaching since 1992. Coached previously in Portugal on Sport Grupo Sacavenense (SGS), Casa Pia Atlético Clube, Futebol Clube Alverca, Real Sport Clube, Oriental Deagon FC under 11,13,15,17 and 19 in Sporting Clube de Portugal under 16 and Povoense senior team. Outside Portugal, coached in Saudi Arabia on Al-Ahli Saudi Football Club under 10 and under 14 teams, and in China on Shandong Luneng under 19 teams. Football start to be part of his life as a player but due to injuries ended up focusing on his coaching career.

The order of the coaches follows the same order of interviews. Before the interviews took place, a brief presentation was prepared with the research questions of this thesis, the main goals, as well as a resume of the proposed framework presented in Chapter 4.2.

Lastly, to retrieve the necessary information and feedback regarding the presented strategy, the coaches answered three questions, and their exact words are going to be transcript in the next section of this document, with due consent.

The three questions were:

---

**Q1** Do you consider the proposed Toolbox Architecture as useful and why? If not, why do you believe it is not?

**Q2** Do you have any criticism of the proposed Toolbox Architecture? Please explain.

**Q3** Would you consider implementing the proposed Toolbox Architecture? Please clarify why/ why not.

**Q4** Do you have any recommendations or suggestions for further improvements to the proposed Toolbox Architecture?

---

The interviews were conducted with each listed coach individually. All agreed on being recorded to write the answers to the three questions in the next chapter of this thesis. The interviews were conducted between August and September 2021.

## 4.5. DISCUSSION

In this section, there are transcriptions of the answers of each expert to the previous questions defined by the author. Everything that is written, was previously recorded and nothing is fictional or made up. It is of tremendous importance that the discussions were honest and the feedback positive, which in this case the author can confirm that both circumstances were accomplished.

**Regarding Q1 “Do you consider the proposed Toolbox Architecture as useful and why? If not, why do you believe it is not?”, the answers were:**

**SJ:** Yes, I find the proposed Toolbox Architecture useful, because it is possible to perspective the current state of affairs and possibly compare with other teams and organizations and see in what stage they are in.

**JP:** Yes, I find it useful since through this application it is possible to gather information to do a better study not only the football game context like also in the level of health and performance of the athletes.

**PN:** In an increasingly digital world and dependent on technology from my perspective yes, I find it useful, the reflection of the data inserted facilitates a lot of the job. The Toolbox Architecture makes you reflect on the importance of the analyse of the data how can we work with them to bring the best performance from everyone involved.

**Concerning Q2, “Do you have any criticism of the proposed Toolbox Architecture? Please explain.”, the answers were:**

**SJ:** On the aspect of Health, the two sub-aspects, injury prevention and physical capability, cannot be covered by technology. Technology cannot cover the player’s day-to-day, mental stress, which can influence the muscle level. There are several variables that technology doesn’t control. Technology can predict some things but on other levels, it cannot adapt. So, my first criticism is that the Toolbox Architecture does not include human factors due to technologies that do not yet allow it. Examples such as amateur level when it comes to day-to-day stress, and on a professional level the media. When you work with humans and you try to be very objective about how things are, you can gain control over some areas that without technology was impossible, but on the other hand, you should always reflect on the information gathered by the data, not seeing it objectively but considering everything else. Other criticism is on the context level, where there is a lap of heterogeneity. I understand that it’s just one application architecture, however, it is difficult to divide it this way because for example on youth academy, Sporting CP, and SL Benfica on theirs under 19 teams they have more technology implemented than clubs from third and even second league in Portugal.

**JP:** I think that the option of not having technology implanted at all must have better importance. Since the majority of the clubs in lower-tier leagues don’t have it and probably will be the option most chosen the range of choices must be affordable for them and by not having the budget implicit is difficult to apply the results of the Application.

**PN:** On the aspects to improve in the team, there are much more aspects out of the ones presented, today football regardless of whether is initiation or not, must also take into account the yield in terms of performance, and from a certain age if under 14, under 16 dependent on the sports background development there is a binomial between youth academy and yield in terms of performance where a lot of other variables must be equated, and one of them is communication.

**About Q3, “Would you consider implementing the proposed Toolbox Architecture? Please clarify why/ why not.”, the answers were:**

**SJ:** Yes, I consider implementing it but depending on the context, whether I had the budget or not. Where I’m currently working I didn’t implement.

**JP:** Yes of course yes. But at the moment the majority of the clubs don’t have the budget for it. The cost of the technology is an impediment to the amateur and youth academy levels. In Portugal, this Application Toolbox is possible to applicate in the second and first leagues.

**PN:** I have some resistance to absolute truths, my fear is that when you create something that can lead you to an algorithm in which by crossing information gives you a result, wherein collective sports especially in football where randomness is permanently present, I have some difficulty in closing everything to a yes or no answer. For example, in football, we can have a team that during the entire time of the game doesn't make a single shot on goal and wins the game one-nil with an own goal conceded by the opponent. Decision support instruments must be considered, but I have some resistance about all of them. One practice example is that if the GPS technology was used by Diego Armando Maradona probably the manager will not choose him to play based only on his GPS stats. In my experience for example when I coached in China, player stats individually were excellent but, in the team, some of the aspects don't show up. So, to conclude, for decision support yes, I consider implementing but with precaution and analyses on the conclusions.

**Lastly, Q4, "Do you have any recommendations or suggestions for further improvements to the proposed Toolbox Architecture?", the answers were:**

**SJ:** When talking about technologies, expenses are implied. Because it encompasses applications, products or human resources that have to be specialized. For example, I can have the budget to buy thirty GPS kits for my team, but not have the resources within the human resources available to draw on valid GPS information to use and increase performance. It is not by having a product or service that the team will increase. To increase performance, you have to use the product, extract objective data from it and make a clear analysis of what is being done. So, I recommend defining a set of parameters based on products that have a set of parameters, for example, limiting the technologies to the budget, and centered on the budget, it is also possible to categorize the club. Another suggestion is within the technologies used, filtering depending on the context. In other words, a GPS that analyses five to six parameters and another weaker one that measures only two parameters will end up being cheaper and more accessible to teams with a smaller budget.

**JP:** The Application Toolbox is simple and easy to use. So, for a high level of football, like divisions one and two I keep it like this. To apply for all of the contexts I recommend being more specific on distinguishing each type of context like youth academy school or youth academy semi-professional, professional high and low level, and this way try to get the best results for each club. Also adding the budget to filter technologies.

**PN:** This Application Toolbox to arrive at a professional level must be improved in many aspects. In this way is a simple support decision tool more for document support. To become an application to be used at the professional level must be taken into consideration all people involved in the actions of the team, more contexts, and more aspects to improve. Also, I recommend that culture and education must be taken into consideration while doing one Application Toolbox Architecture since those aspects can influence a lot the way players act and play.

## **5. CONCLUSIONS**

The last chapter of the thesis aims to answer the first chapter research questions and objectives. The reason for that is so the Conclusion can simplify if the described research questions and the proposed objectives in the Introduction have been answered and fulfilled, accordingly. Following the research methodology of football, the importance of coaches, Information Systems and Computer-based Technology for football it is safe to say that this thesis will add value to the Football community, more specifically, to Football Coaches. The Application Toolbox Architecture idealized was well received in the validation phase but with some aspects to improve. During the Conclusion, there is presented a synthesis of all the work done during the development of the thesis, then, there are described the limitations for this research, and finally, the future work and possibilities of what this research possibly will bring.

### **5.1. SYNTHESIS OF THE DEVELOPED WORK**

The methodology for this dissertation has resulted from a traditional following procedure considering a DSR. The study objective was for the creation of an application Toolbox architecture for football coaches to help them improve the performance of their teams. A literature review was organized with the condition of searching the most recent scientific papers. The actual framework was created based on the previous steps and with the knowledge of the author. Then, the framework went through a validation phase by three football coaches. This process was done by individual interviews, where the author presented the topic and gave plenty of time for any questions from the professionals. By the end of the interviews, the author had the feedback and opinion from them. They approved the framework and gave suggestions for improvement. With those feedbacks, the strategy was evaluated and was declared as ready for implementation in the football world. It is safe to say, that the initially proposed objectives were fulfilled, and the research questions were answered, giving meaning to this research.

### **5.2. LIMITATIONS**

In every research, there are certain limitations that the authors came across, and this thesis was no exception. This topic was developed as part of obtaining a master's degree, so the time invested was already defined in the beginning, giving a sense that there were always opportunities to improve the research. The first obvious limitation is the number of interviewed specialists. Of course, the more interviews were done, the better. This "limitation" should be seen as a temporal clause. As it was possible to understand in the previous chapter, the use case described using the proposed framework was a simulation. The author tried to simulate as near to reality as possible, though, it will never have the possibilities and variables of a real-world use case. Since this research followed the rules of a DSR, it is missing the last phase, the Communication phase. This last phase is a process that can take from weeks to years to be accomplished. It would not be possible to wait for any kind of approval to publish the research in a recognized journal. Also, the Communication phase depends on the engagement and feedback from the community in which each specific research inserts. The second limitation pass through the budget was not taken into consideration. However, technologies prices are becoming more and more affordable due to the banalization of technologies in sports, so the budget if included

must be variable, and at the moment this Application Toolbox Architecture is considered limited to the team's budget given current technology prices.

### **5.3. FUTURE WORK**

The work that could be done in the future to add value to this research can achieve the previous limitations reached. It is important to mention, that for future work, the presence of the author is not mandatory. Since the developed strategy had the main focus of achieving a master's degree, this document will be available to every researcher that should search for these topics. It is important to spread the topic in the football clubs in all divisions to understand the needs of the clubs and the focus should be not only the football coaches but also the enterprises that produce these technologies, since the adaptation of the cost will come from them, in order to become possible to implement technology in all football divisions with low costs. The inclusion of a variable budget to adapt to the variation of technologies prices is a must and the key factor to make this Application Toolbox a reality between all football clubs.

## BIBLIOGRAPHY/REFERENCES

- A. J. Strudwick. (2012). Contemporary issues in the physical preparation of elite players. In *Science and Soccer* (3rd ed.).
- Allan, V., & Côté, J. (2016). A Cross-Sectional Analysis of Coaches' Observed Emotion-Behavior Profiles and Adolescent Athletes' Self-Reported Developmental Outcomes. *Journal of Applied Sport Psychology, 28*(3). <https://doi.org/10.1080/10413200.2016.1162220>
- Almulla, J., Takiddin, A., & Househ, M. (2020). The use of technology in tracking soccer players' health performance: A scoping review. *BMC Medical Informatics and Decision Making, 20*(1). <https://doi.org/10.1186/s12911-020-01156-4>
- Barron, D., Ball, G., Robins, M., & Sunderland, C. (2018). Artificial neural networks and player recruitment in professional soccer. *PLoS ONE, 13*(10). <https://doi.org/10.1371/journal.pone.0205818>
- BIHub Team. (2020a, July 6). *HOW PIXELLOT'S AI TECHNOLOGY WORKS TO STREAMLINE WORKFLOWS AT FC BARCELONA*. <https://barcainnovationhub.com/how-pixellots-ai-technology-works-to-streamline-workflows-at-fc-barcelona/>
- BIHub Team. (2020b, July 16). *PART I: THE STORY BEHIND THE COLLABORATION BETWEEN WIMU AND BARÇA*. <https://barcainnovationhub.com/part-i-the-story-behind-the-collaboration-between-wimu-and-barca/>
- BIHub Team. (2021, March 5). *BARÇA INNOVATION HUB AND PIXELLOT DEVELOP NEW AUTOMATED RECORDING SYSTEM FOR BARÇA ACADEMIES AND GRASSROOTS FOOTBALL*. <https://barcainnovationhub.com/barca-innovation-hub-and-pixelot-develop-new-automated-recording-system-for-barca-academies-and-grassroots-football/>
- Brink, M. S., Nederhof, E., Visscher, C., Schmikli, S. L., & Lemmink, K. A. P. M. (2010). *Monitoring Load, Recovery, and Performance in Young Elite Soccer Players*. [www.nsca-jscr.org](http://www.nsca-jscr.org)
- Buchheit, M., Allen, A., Poon, T. K., Modonutti, M., Gregson, W., & di Salvo, V. (2014). Integrating different tracking systems in football: multiple camera semi-automatic system, local position measurement and GPS technologies. *Journal of Sports Sciences, 32*(20), 1844–1857. <https://doi.org/10.1080/02640414.2014.942687>
- C. Carling, & M. Court. (2012). Match & motion analysis of soccer. In *Science and Soccer* (3rd ed., pp. 173–198).
- Cambridge Dictionary*. (2020).
- Capobianco, G., Giacomo, U. di, Mercaldo, F., Nardone, V., & Santone, A. (2019). Can machine learning predict soccer match results? *ICAART 2019 - Proceedings of the 11th International Conference on Agents and Artificial Intelligence, 2*, 458–465. <https://doi.org/10.5220/0007307504580465>

- Carling, C., le Gall, F., McCall, A., Nédélec, M., & Dupont, G. (2015). Squad management, injury and match performance in a professional soccer team over a championship-winning season. *European Journal of Sport Science*, 15(7), 573–582. <https://doi.org/10.1080/17461391.2014.955885>
- Claudino, J. G., Capanema, D. de O., de Souza, T. V., Serrão, J. C., Machado Pereira, A. C., & Nassis, G. P. (2019). Current Approaches to the Use of Artificial Intelligence for Injury Risk Assessment and Performance Prediction in Team Sports: a Systematic Review. In *Sports Medicine - Open* (Vol. 5, Issue 1). Springer. <https://doi.org/10.1186/s40798-019-0202-3>
- Coutts, A. J. (2014). Evolution of football match analysis research. *Journal of Sports Sciences*, 32(20). <https://doi.org/10.1080/02640414.2014.985450>
- Cruyff, J. (2016). *My Turn: The Autobiography*.
- Davila, A., Foster George, & Llopis Jaume. (2007). Futbol Club Barcelona. Globalization opportunities. *Stanford University*.
- Dessing, J. C., & Craig, C. M. (2010). Bending it like Beckham: How to visually fool the goalkeeper. *PLoS ONE*, 5(10). <https://doi.org/10.1371/journal.pone.0013161>
- Ehrmann, F. E., Duncan, C. S., Sindhusake, D., Franzsen, W. N., & Greene, D. A. (2016). *GPS AND INJURY PREVENTION IN PROFESSIONAL SOCCER*. [www.nasca.com](http://www.nasca.com)
- Ferrer, C. D. R., Shishido, H., Kitahara, I., & Kameda, Y. (2020). Read-the-game: System for skill-based visual exploratory activity assessment with a full body virtual reality soccer simulation. *PLoS ONE*, 15(3). <https://doi.org/10.1371/journal.pone.0230042>
- FIFA. (2001). *FIFA Survey: approximately 250 million footballers worldwide*. <https://www.fifa.com/who-we-are/news/fifa-survey-approximately-250-million-footballers-worldwide-88048>
- FIFA. (2006). *2006 Fifa World Cup Germany*. <https://www.fifa.com/worldcup/archive/germany2006/>
- FIFA. (2007). *The History of Football*. <https://www.fifa.com/news/the-history-football-425>
- FIFA. (2020). *Electronic Performance & Tracking Systems*. <https://football-technology.fifa.com/en/media-tiles/epts-1/>
- Gates, B. (1999). *Business at the Speed of Thought : Using a Digital Nervous System*. Little, Brown & Company.
- Hevner, A. (2004). *Design Science in Information Systems Research*. <https://www.researchgate.net/publication/201168946>
- Hoppe, M. W., Baumgart, C., Polglaze, T., & Freiwald, J. (2018). Validity and reliability of GPS and LPS for measuring distances covered and sprint mechanical properties in team sports. *PLoS ONE*, 13(2). <https://doi.org/10.1371/journal.pone.0192708>



- Infoholic Research. (2017, February). *Worldwide Sports Analytics Market to grow at a CAGR of 40.1% during the forecast period 2016–2022 to aggregate \$3.97 billion by 2022*.  
<https://www.infoholicresearch.com/press-release/worldwide-sports-analytics-market-to-grow-at-a-cagr-of-40-1-during-the-forecast-period-2016-2022-to-aggregate-3-97-billion-by-2022/>
- Jovanovic, M., Sporis, G., Omrcen, D., & Fiorentini, F. (2011). *Effects of speed, agility, quickness training method on power performance in elite soccer players*. [www.nscj-jscr.org](http://www.nscj-jscr.org)
- Kattuman, P., Loch, C., & Kurchian, C. (2019). Management succession and success in a professional soccer team. *PLoS ONE*, 14(3). <https://doi.org/10.1371/journal.pone.0212634>
- Kellmann, M. (2010). Preventing overtraining in athletes in high-intensity sports and stress/recovery monitoring. *Scandinavian Journal of Medicine & Science in Sports*, 20.  
<https://doi.org/10.1111/j.1600-0838.2010.01192.x>
- Ken Peffers, Tuure Tuunanen, Charles Gengler, Matti Rossi, Wendy Hui, Ville Virtanen, & Johanna Bragge. (2006). The design science research process: A model for producing and presenting information systems research. *DESRIST*.
- Kitching, G. (2015). *“The Origins of Football”: History, Ideology and the Making of ‘The People’s Game.’* <https://ssrn.com/abstract=2897953>
- Magee, C. (2015). *Investors Swing For The Fences With \$1B In Sports Tech Deals*.  
<https://techcrunch.com/2015/04/24/investors-swing-for-the-fences-with-1b-in-sports-tech-deals/>
- Meng, X., Li, Z., Wang, S., Karambakhsh, A., Sheng, B., Yang, P., Li, P., & Mao, L. (2020). A video information driven football recommendation system. *Computers and Electrical Engineering*, 85.  
<https://doi.org/10.1016/j.compeleceng.2020.106699>
- O’Brien, J. A., & Marakas, G. M. (2010). *Introduction to Information Systems: Essentials for the Internetworked Enterprise* (15th ed.).
- Orlikowski, W. J., & Iacono, C. S. (2001). Research Commentary: Desperately Seeking the “IT” in IT Research—A Call to Theorizing the IT Artifact. *Information Systems Research*, 12(2).  
<https://doi.org/10.1287/isre.12.2.121.9700>
- Pappalardo, L., Cintia, P., Rossi, A., Massucco, E., Ferragina, P., Pedreschi, D., & Giannotti, F. (2019). A public data set of spatio-temporal match events in soccer competitions. *Scientific Data*, 6(1), 236. <https://doi.org/10.1038/s41597-019-0247-7>
- Pons, E., García-Calvo, T., Resta, R., Blanco, H., del Campo, R. L., García, J. D., & Pulido, J. J. (2019). A comparison of a GPS device and a multi-camera video technology during official soccer matches: Agreement between systems. *PLoS ONE*, 14(8).  
<https://doi.org/10.1371/journal.pone.0220729>
- Rein, R., & Memmert, D. (2016). Big data and tactical analysis in elite soccer: future challenges and opportunities for sports science. In *SpringerPlus* (Vol. 5, Issue 1). SpringerOpen.  
<https://doi.org/10.1186/s40064-016-3108-2>

- Rossi, A., Pappalardo, L., Cintia, P., Iaia, F. M., Fernández, J., & Medina, D. (2018). Effective injury forecasting in soccer with GPS training data and machine learning. *PLoS ONE*, *13*(7).  
<https://doi.org/10.1371/journal.pone.0201264>
- Smith, M. (2018, January 31). *Manchester City have spent more on defence than 52 COUNTRIES after £57m signing of Aymeric Laporte*. <https://www.dailymail.co.uk/sport/football/article-5333605/Man-City-spent-defence-52-COUNTRIES.html>
- STATSports. (2020). *STATSports* . <https://statsports.com>
- Stein, M., Janetzko, H., Seebacher, D., Breitzkreutz, T., Schreck, T., Cauzin, I., Grossniklaus, M., & Keim, D. A. (2016). *Director's Cut: Analysis and Annotation of Soccer Matches*.
- Trewin, J., Meylan, C., Varley, M. C., & Cronin, J. (2017). The influence of situational and environmental factors on match-running in soccer: a systematic review. In *Science and Medicine in Football* (Vol. 1, Issue 2, pp. 183–194). Taylor and Francis Ltd.  
<https://doi.org/10.1080/24733938.2017.1329589>
- Turner, A. N., Bishop, C., Cree, J., Carr, P., McCann, A., Bartholomew, B., & Halsted, L. (2019). Building a High-Performance Model for Sport. *Strength and Conditioning Journal*, *41*(2).  
<https://doi.org/10.1519/SSC.0000000000000447>
- World's Most Popular Sports. (2010). *World's Most Popular Sports*.  
<https://mostpopularsports.net/in-the-world>

