Distributed Crowd-based Annotation of Soccer Games using Mobile Devices

Bruno Barros[1], Carlos Serrão[2] and Rui Lopes[3]
[1]*Instituto Universitário de Lisboa (ISCTE-IUL), Av. das Forças Armadas, 1649-026 Lisboa, Portugal*
[2]*Information Sciences, Technologies and Architecture Research Centre (ISTAR-IUL), (ISCTE-IUL), Lisboa, Portugal*
[3]*Instituto de Telecomunicações (IT), (ISCTE-IUL), Lisboa, Portugal*
{bruno_barros, carlos.serrao, rui.lopes}@iscte-iul.pt

Keywords: Soccer, Annotation, Mobile Application, Distributed Crowd-Sourcing.

Abstract: Soccer is one of the most loved sports in the world. Millions of people either follow the sport or are actually involved in its practice. Soccer also moves huge financial amounts every year and therefore teams always thrive to be better than the competition. New technologies have become a common place both in the preparation of the games and on the analysis of the games after they are concluded. In this paper, the authors will present a developed system, based on the usage of distributed mobile devices, that will enable the annotation of soccer matches, either in real time or after the matched is concluded (through the observation of other media). The capture of relevant events in the game can be used to better analyse the game and the performance of individual players fostering improvements and better decisions in the future. The application is implemented in the Android platform so that it can be easily installed by typical soccer fans empowering them as match annotators. This crowd of annotators, although not experts, can collectively provide a robust and rich annotation for soccer matches.

1 INTRODUCTION

Information technology is present in many aspects of our live. Sports are a very special case of technology application where mobile smart devices can play an important role. On the individual and personal side, it is more and more common to support the practice of a given specific sport activity, such as running, walking or swimming, on the data collected by smart devices, equipped with several sensors. Smartphones and smartwatches are charged with multiple motion (e.g., accelerometers, altitude), GPS/location and heartbeat sensors that track their users sport activities and produce detailed reports about their performance. This is a common trend that can be easily confirmed simply by looking to every person conducting some type of exercise.

Although these personal devices are adequate to capture individual performance, they lack the capability of analyzing collective sports such as soccer, or better, they are able to determine the individual physical performance of the players but they are unable to capture their actions in the match field. In order to acquire the capability of capturing the players actions and analyze a soccer match as a whole, annotation tools are often used.

Moreover, these annotation tools are often used by soccer clubs that have the capability of making large investments in specialized hardware and software (e.g., GPS tracking (STATsports, 2018)) and dedicated team members to annotate the games (either through automated or manual video analysis, e.g., data streams (Liu et al., 2013; OPTAsports, 2018)) and extract information from them. However, teams without the necessary financial resources to acquire such systems do not have the opportunity to annotate their games and thus extract the required knowledge to improve their players' actions on the field and improve as a team. A particular example of this are young age soccer teams, in particular those involved in the development/formation of young players, where both team performance and young talent scouting can capitalize from the annotation of team and players' performance (Fernandez-Rio and Méndez-Giménez 2014; Müller, Simons, and Weinmann 2017; Pastor-Vicedo, Contreras-Jordán, and Prieto-Ayuso 2017).

On the other hand, using large communities (i.e., crowd-sourcing (Howe, 2006; Zhao and Zhu, 2014) for solving large complex tasks has proven to be a valuable source of data. This concept has already successfully been applied in the real of sport events

Barros, B., Serrão, C. and Lopes, R.
Distributed Crowd-based Annotation of Soccer Games using Mobile Devices.
In *Proceedings of the 6th International Congress on Sport Sciences Research and Technology Support (icSPORTS 2018)*, pages 40-48
ISBN: 978-989-758-325-4

and media (Perin, et al., 2013; Sulser, et al., 2014). In the particular case of young players' teams there is a particular interest on their progress and achievements from parents and other relatives, which usually attend to their matches and are thus a significant, and cheap, resource pool (crowd) of annotators (Fernandez-Rio and Méndez-Giménez, 2014; Pastor-Vicedo, et al., 2017). That is, using the potential of distributed and mobile annotation applications can help young player team managers/coaches to develop training processes to improve the individual skills of each individual player and the team as an all. Additionally, the need to have specific team members to annotate the games is mitigated, due to the fact that any of the users of the distributed mobile annotation application, can annotate the games - for instance, parents of the players can annotate the games, contributing to the collection of game events for the team or club.

In this paper, a tool for the distributed annotation of soccer matches is presented and described, based on the usage of mobile devices, such as smartphones or tablets. As first section of this paper, an introduction to the usage of technologies in sports and of the different approaches that are used for annotation on soccer matches is provided, highlighting their major advantages and disadvantages. In the second section of the paper the description of the distributed soccer match annotation tool is provided, with information regarding the different choices that were made concerning the design of the mobile application and the implementation of the distributed annotation algorithm. Following this, the description of a specific soccer match annotation use-case is presented as a way to evaluate the developed solution. Finally, the last section presents the conclusions of this work and draws the directions for some future work.

2 OVERVIEW OF SOCCER MATCH ANNOTATION SOLUTIONS

Annotation of soccer matches is an important tool for the soccer game intelligence collection, both in terms of the evaluation of the individual players and the overall team performance. There are already numerous solutions that are used for game annotation. In this analysis, it is possible to categorize the existing tools according to three different axes: focus, collection and context. Focus is concerned about the object where the annotation events are collected (team or individual player). Collection refers to the type of data collection being made, and it can be manual or automated. Context refers to where the data is collected, if the collection is made in real time, from the field, or from some pre-recorded video.

For the sake of the analysis presented here, we have considered just one dimension - collection. For this dimension it is necessary to consider systems that collected data from games manually or automatically.

2.1 Manual Annotation Solutions

Opta is a commercial system that allows the manual collection of events from a soccer match (OPTAsports, 2018). It uses is own computer application and requires specialized trained operators to manually collect the events from a video live feed or from recorded video feed. It requires two annotators, one for each of the teams. Opta is a professional solution that produces statistics that are afterwards analysed by professional soccer leagues (Liu et al., 2013).

Another interesting solution is SAP Sports One for Football (SAP News Center, 2017), although not targeting specifically the annotation of games. This solution is designed for football clubs and associations and is capable of handling different types of data, such as match statistics, player fitness data, information about injuries, medication, and recovery, training data, match analyses, and scouting.

A popular application is Longomatch (Longomatch, 2011). Longomatch is also a system for manual collection of soccer match events, mostly based on either recorded or live video. It also allows the edition and annotation of videos to prepare specific trainings or instruct the players about some of the movements they should conduct on the field during the game.

In the mobile realm, the Muithu touch system (Stenhaug et al., 2014) allows to annotate sport events using mobile devices. The different interaction screens are organized in a hierarchical way where, by selection and dragging, players can be associated to their actions.

2.2 Automated Annotation Solutions

There are currently several automated soccer match annotation solutions, all of them targeting professional soccer teams, mostly because of their costs. Most of these solutions involve the analysis of images captured from the field. An example of such is the Bagadus sports analytics application that uses soccer as a case study (Halvorsen et al., 2013). In the Bagadus system, annotations provided via the Muithu

touch system, are combined with the result of a sports analytics module that processes data from on a video processing system using a video camera array. (Pettersen et al., 2014) (the ZXY Sport Tracking system).

(Duh et al., 2013) also propose an automatic process to analyse soccer matches broadcast video for the detection and tracking of players based on the automatic classification of the video into different scenes based on 2-D Gaussian colour model of hue and saturation, and the analysis of the player actions.

A framework for semantic annotation of soccer videos that exploits an ontology model referred to as Dynamic Pictorially Enriched Ontology is proposed by (Ballan et al., 2010). In this framework, visual instances are used as matching references for the visual descriptors of the entities to be annotated on the match.

Interplay (Interplay-sports., 2017) is a private company that offer a set of products that are also used to conduct automated analysis of live and video from different types of sports - soccer included.

3 REQUIREMENTS FOR A CROWD-SOURCE ANNOTATION APPLICATION

From the analysis conducted in the previous section of this paper, it was possible to conclude that most of well-known and financial powerful soccer clubs in the World are already incorporating IT on their players training processes, both to capture data about their performance, but also to discover ways on how to improve their results. Also, there are currently different soccer matches annotations solutions that are a mix of expensive and perfectly calibrated hardware on the field with proprietary software analysis tools. There are others that extremely personal intensive, demanding a permanent team to capture data from recorded videos in order to analyse the soccer matches. These are solutions that are not accessible to most soccer clubs and are completely off limits in the specific case of young players formation and training.

Therefore, current solutions are not adequate for the purpose referred above and different solutions need to be used. In this specific case, inexpensive and lightweight match annotation solutions are required to enable smaller soccer teams/clubs and young players formation to use low-cost technology, such as smartphones and tablets, to annotate live or pre-recorded matches, in a distributed manner. Annotation can be performed not only by the team staff, but also by other external elements. For instance, team fans while watching the game can contribute to the annotation of the game using their own mobile devices (Zhao and Zhu, 2014). Also, family members of the young players can also annotate the games where their relatives participate.

The solution presented in this paper is based on using distributed mobile devices to annotate soccer games. Multiple users can annotate the same game, and some users can annotate one of the teams, while other users can annotate the adversary. This way, it will be possible to collect a higher number of game events with a richer detail. This information is collected, stored post processed. The post processing of the collected data can be used to conduct a set of actions:

- Analyse the overall team performance and individual performance of a given player - identify the team behaviour in different moments and aspects of the game, in particular, comparing that performance with the adversary opposition;
- Create game statistics - offer a statistical treatment of all the data collected to provide better ways to analyse and visualize the game;
- Improve training processes - identify which are the specific needs in terms of training to help the coach to design better precise training techniques focusing on the group or on individual players;
- Discover new talents - finally, the solution can also be used to identify new and talented players (scouting).

4 IMPLEMENTATION OF A CROWD-BASED DISTRIBUTED SOCCER GAME ANNOTATION SYSTEM

As a way to achieve the overall objectives of an effective distributed game solution the authors opted by designing a system that would take advantage of the extreme mobility presented by the nowadays end-user devices and developed a mobile application (for the Android platform) that would provide the annotation capabilities required by a soccer match.

The system is composed by a set of different components that enable data collection at the end-user side and posterior storage at a backend system. Figure 1 displays the different architectural components of the annotation system developed.

Figure 1: Architecture overview of the distributed annotation system.

The fact that the system is designed deliberately taking into consideration multiple, simultaneous annotations (from the crowd), distinguishes it from other mobile solutions.

The system is based on a client-server architecture. On the client-side, the users will interact with the mobile application, which will present an interface that will adapt according to the different conditions of the game. The mobile application uses a REST API that is implemented and the server side, and that allows the application to retrieve all the information it needs about the soccer match and the different players information (the REST API was developed using PHP). Moreover, this API will enable the mobile application to communicate the annotations captured by the user on a specific soccer match. All of this information is stored on a database (a MySQL database).

Another important function on the server is the ability of aggregating all the different annotation events captured by different users (different users may be annotating the same match and the same team), creating an integrated and consolidated "view" on the data of the events occurred during the game. This consolidated view is also stored on the database for further statistical analysis, that will provide the necessary feedback to improve the players and training performance.

4.1 The Data Collection Mobile Application

The application was developed for Android smartphones and tablets. Special focus was placed on the design and responsiveness of the user-interface since it is one of the most critical components of the system. Simplicity was thus one of the major concerns on the design of the interface. A proper-designed user interface will allow the human annotator to capture more and better data about the soccer match events (which is not an easy task, taking into consideration the event speed occurrence on some matches).

As it is possible to notice in Figure 2, the mobile application presents on the initial screen, the different elements necessary for the user to start taking annotations. On the beginning of the game, the annotator selects the team that he will be annotating, and it is possible for other users to select the same team or the opponent team.

Figure 2: Initial screen of the annotation application.

As soon as the user starts annotating the events on the game, the mobile application user interface will change and adapt to the new event that needs to be annotated. For instance, Figure 3 displays the screen that is presented to the user when a player attempts a shot on goal. In this screen it is presented all the options that may occur on that situation, including the direction of the shot towards the goal.

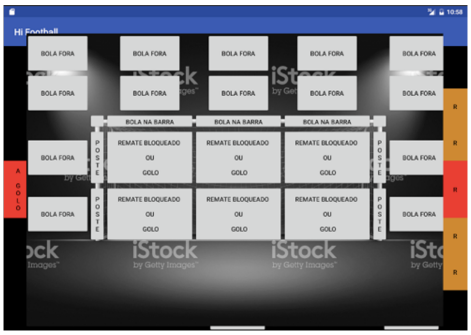

Figure 3: Shot screen displaying the different annotation events.

This sequence of screens, resulting from a sequence of events occurring on a soccer match were defined and implemented on the annotation state machine, presented on the next section, that allows the user, to naturally capture the different events that occur inside the field. This way, the usage of a distributed system, will allow the collection of larger number of events for both of the opposing teams, that will be afterwards sent to the server and stored, and aggregated and consolidated to provide an integrated and faithful textual annotated view of the game. All of this data collected will be used posteriorly to produce detailed statistical information about the team and individual players, allowing the trainers and the players themselves to work towards the improvement of their performance and development.

4.2 Annotation State Machine

One of the concerns that the team had during the development of the system, was to adapt it to be as simple as possible for the user to annotate the games. A state machine was created to mimic the most common situations of a soccer match to help the annotator to capture a larger number of events. It was possible to identify from other systems and from the existing literature, which were the most relevant events on a football match (Carling, Reilly, and Williams 2007). In order to simplify the process, each annotator only follows a specific team so that the user interface only details the specifics of that team on a specific situation. The most basic part of this state machine refers to the events occurring between the start and the end of the match (Figure 4). The focus on simplicity of interaction lead us to three design options that differentiate our system: i) the annotation state machine is based on atomic events/actions (e.g., player A has the ball), ii) only these atomic events are stored in the database, iii) non-atomic events (e.g., a pass from player A to B) are obtained from atomic events during the post-processing and not annotated explicitly in the mobile device.

The first event to occur on a game is the "kick off" event, so the first state is to show the user the “Kick Off Screen”. After this, a specific player has the ball, and pressing on the player button, will bring the “Offensive Screen” to the user, where it will annotate the event, by switching between different players, until the game reaches halftime, where the “Halftime Screen” is presented, or the game ends, bringing the “Initial Screen”. During this annotation period, the player may change roles, between offensive and defensive actions, therefore switching between the “Offensive” and “Defensive Screens”.

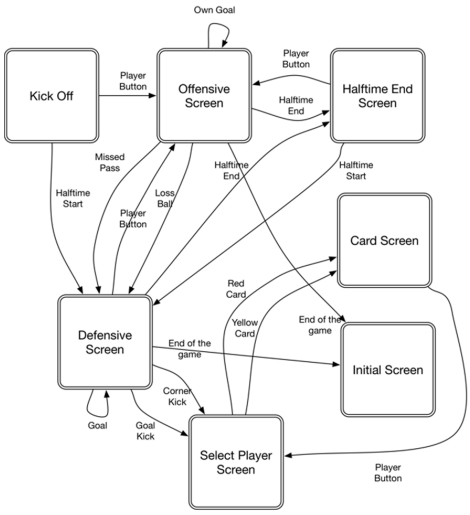

Figure 4: Basic soccer game state machine.

The state machine will result on a set of events and screens that are presented to the users. The following is a list of screens presented to the annotators:

- Initial Screen: this screen is displayed when the application starts or when a game ends;
- Kick Off Screen: the initial state, waiting for one of the teams to kick off the game;
- Offensive Screen: this screen displays the team while possessing the ball, to collect offensive events;
- Halftime End Screen: the screen is displayed at halftime and waits for a new kick off;
- Defensive Screen: the screen is displayed when the team doesn't have the ball, used to collect the defensive events;
- Goal Kick Screen: this screen collects all the possible outcomes of a shot, necessary for the annotator to select the type of goal kick that occurred (shot off, goal kick, and others);
- Foul Screen: the screen displays the offensive and defensive infractions (for instance, foul, penalty, and others);
- Select Player Screen: displays all the players on the field and allows to select a player that will take an action, when the ball is stopped (corner kicks, throw ins, fouls, penalties, and others);
- Select the Faulty Player Screen: displays all the players on the field to allow the selection of the player that as committed a foul;

- Card Screen: displays all the players on the screen that allows the registration of cards the player has received (yellow or red cards).

In the presented screens, different events may occur. The way for the annotator user to record such events is through different buttons:

- Player Button: records the player that received the ball - has possession of the ball;
- Halftime Start: registers the beginning of the game or the beginning of the second half;
- Halftime End: signals the end of one of the game halftimes;
- End of the Game: signals the end of the game;
- Own Goal: registers the player that scored an own goal;
- Ball Loss: registers the player that has lost the ball possession;
- Yellow (Red) Card: registers that a specific player has received a yellow (red) card;
- Corner (Goal) Kick: registers that the team has been awarded a corner (goal) kick;
- Throw in: records a throw in;
- Foul: brings the Foul Screen, selects the foul and records if it is a defensive or offensive foul;
- Goal: registers the player that scored a goal, awarding the ball possession to the opponent team;
- Blocked Kick: records the player that had a kick attempt blocked;
- Shot off: records the player that attempted a shot to the goal and the ball goes off;
- Post (Bar) Shot: records the player that shoot the ball to the post (bar);
- Foul Awarded: records the foul that was committed on a player;
- Foul Committed: records the foul that was committed by a player;
- Penalty Awarded: register the penalty that was committed on a given player.

The state machine allows the modelling of all the possible situations on the soccer match (Figure 5), allowing the annotation user to capture a larger number of events occurring on the game. The state machine, implemented on the mobile application allows the different appropriated annotation screens to be presented to the end user, according to the different events that occur on the game.

5 SOCCER MATCH ANNOTATION USE-CASE

After the development of the distributed annotated mobile application the system was tested with real users in a controlled environment. Users were invited to annotate a soccer match sequence, based on a video, where all the relevant events have been previously captured. The basic idea with these tests was to evaluate how the users, using the mobile application, were able to accurately identify the events that were displayed on the match video sequence.

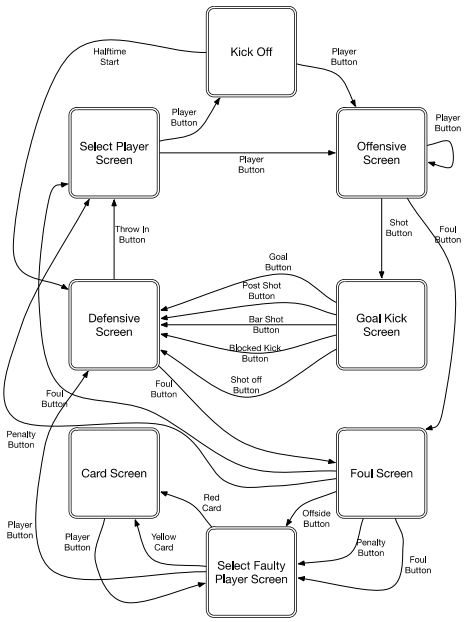

Figure 5: State machine that describes the different moments on a soccer match.

The video used on the tests with the users, with a duration of around 10 minutes, was composed of several other shorter video sequences containing different types of events on a soccer match. The idea of the tests was to simulate the real environment conditions that an annotator user would find on a real match. Therefore, the video was visualized uninterruptedly, without the possibility of rewinding it, and the events observed by the user on the video were annotated, in real time, on the application. The results from the tests conducted with several different types of users are presented on Table 1, where que

number of different events that are presented by the video to the testing user are recorded (E1), the average number of recorded events by the different users on the annotation application developed are presented (E2) and the average number of correctly identified and recorded match events are also depicted (E3). On the table it is also presented the accuracy level for each of the correct identified events (AC). The tests were conducted on different users, representing a different skillset on the usage of mobile technologies (smartphones and tablets) and mobile applications. Also, the users did not have any previous contact with the developed application or with any other existing soccer match annotation technologies.

Table 1: Results of the tests conducted on the system to evaluate how users were collecting the events on a sample soccer match video. **E1**: Refers to the number of events that actually exist on the sample video; **E2**: refers to the average number of events annotated by the users testing the application on the sample video; **E3**: refers to the average number of events that were correctly identified by the users testing the application; **AC**: refers to the accuracy of the correct event identification by the users.

Events	E1	E2	E3	AC
Kick-off	1	1	1	100%
Failed pass	16	13	10	63%
Throw-in awarded	6	5	5	83%
Passes	116	102	77	66%
Foul awarded	2	3	2	100%
Goal	3	3	3	100%
Blocked shot	5	2	2	40%
Ball recovery	24	21	19	79%
Committed foul	3	3	3	100%
Corner kick awarded	3	3	3	100%
Shot off	3	5	3	100%
Post shot	2	1	1	50%
Off-side	1	1	1	100%
Halftime end	1	1	1	100%
Ball possession lost	4	2	3	75%
Game end	1	1	1	100%

From the analysis of the results obtained and presented on Table 1, the most obvious conclusion that can be drawn is that there is a slight discrepancy between the number of events actually existing in the soccer match video and the number of events that were annotated by the users. The average accuracy percentage is 85%, allowing us to conclude that the developed solution can indeed contribute to the collection of a large number of events happening on a soccer match. The obtained value can even be improved if we consider the consolidation of the annotated events by the different users that independently can annotate the same match and the same team (which is actually one of the functionalities of the developed system).

Another interesting conclusion from the evaluation and tests conducted on the developed solution is that there are some events in the match game that are more easily recorded by the user annotators than others. For instance, failed passes, blocked shots and post shots are among the most difficult events for users to record on the application. On the other side, kick-off, fouls, corner kicks, off-sides, goals and game end are some of the easiest events to record on the application. There is a factor that contributes to this difference in the identification of events - time. Most of the events with a higher accuracy ratio are events that require the soccer match to stop (or at least pause for some time) making the task easier for the users, that have more time to record such events.

These results allow us to conclude that the developed solution, if we consider the aggregation of the different users annotating the same game, can contribute to an accurate annotation of a soccer match. Considering that the tests were conducted on a controlled environment, using a soccer match video sequence and not the real match on the field, the results may differ. However, it was important to conduct these tests on a controlled environment to have the opportunity to capture the opinion of the users annotating the game, through interviews after the tests, to learn the opinion of the user about the system.

6 CONCLUSIONS AND FURTHER WORK

The technology is more and more present in almost every sport. With technology, it is possible to better analyse the game and the players and find opportunities to improve players performance. The presented system is an example of how technology can play an important role on the annotation of soccer matches, as a way to discover new talented players, study the behaviour of the players and team on the field, and find individual or group improvement opportunities.

The presented system was developed using a client-server paradigm, where one of the most important components of the system was a mobile application capable of running on smartphones and tablets and representing the major communication interface with the user that plays an important role on

the system - the annotation of soccer matches. Special care was dedicated to the design of this mobile application, because, in order to be efficient, it would have to represent the different moments and events that occur during a soccer match as best as possible. The state machine that makes this possible is also presented on this paper, where it is possible to understand the different flow of screens (and the corresponding user interface) appearing to the user annotating the games, reacting to the different choices the user makes on each individual screen. The authors of this system opted by allowing each user to follow only one of the teams on the match field (to maximize efficiency) and also to allow multiple different users to annotate the same team concurrently. This concurrent annotation of the events on the soccer match decisively contributes to a much complete identification of all of them, through a posterior aggregation and consolidation of all the collected data.

The system was tested using different users, with different mobile application usage backgrounds, and without no knowledge of sports annotation tools. From the evaluation conducted, it was possible to conclude that the system is able to accurately allow the collection of the soccer match events, although some limitations were also identified. The tests focused more on the individual annotation task of each of the users, and therefore it was not yet possible to conclude if the aggregation of data from the different users could increase the event collection accuracy levels.

The work described on this paper focused primarily on the quality of the collection of data of events occurring on a soccer match. The second stage of this work, that was not presented here, relates to the processing of the collected data to produce accurate statistics about the team and individual players performance. This statistical information will be of great value for all the different stakeholders involved in the soccer team, mainly for the team managers and players, and will help the democratization of the usage of advanced IT to help smaller professional soccer teams, or even for young players training teams.

There are still some open issues that will need to be tackle while we continue the research and implementation of this system. The first one refers to the huge amount of data will be collected either by this system (where a crowd-based approach is used) or by other sensor-based systems (Rein and Memmerte 2016). The second issue to consider refers to the quality of the collected data, since most of the annotators have no or little experience on soccer match annotations (Hsueh, Melville, and Sindhwani 2009; Nowak and Rüger 2010).

ACKNOWLEDGEMENTS

The authors would like to acknowledge the FCT Project UID/MULTI/4466/2016.

REFERENCES

Ballan, Lamberto, Marco Bertini, Alberto Del Bimbo, and Giuseppe Serra. 2010. “Semantic Annotation of Soccer Videos by Visual Instance Clustering and Spatial/Temporal Reasoning in Ontologies.” *Multimedia Tools and Applications* 48(2): 313–37. https://doi.org/10.1007/s11042-009-0342-4.

Carling, Christopher, Thomas Reilly, and A Mark Williams. 2007. *Handbook of Soccer Match Analysis: A Systematic Approach to Improving Performance*. Routledge.

Duh, Der-Jyh, Shu-Yu Chang, Shu-Yuan Chen, and Cheng-Chung Kan. 2013. “Automatic Broadcast Soccer Video Analysis, Player Detection, and Tracking Based on Color Histogram.” In *Intelligent Technologies and Engineering Systems*, , 123–30.

Fernandez-Rio, Javier, and Antonio Méndez-Giménez. 2014. “Talent Detection and Development in Soccer: A Review.” *Journal of Sport and Health Research* 6(1): 7–18.

Halvorsen, Pål et al. 2013. “Bagadus: An Integrated System for Arena Sports Analytics: A Soccer Case Study.” In *Proceedings of the 4th ACM Multimedia Systems Conference*, MMSys ’13, 48–59. http://doi.acm.org/10.1145/2483977.2483982.

Howe, Jeff. 2006. “The Rise of Crowdsourcing.” *Wired Mag.* 14(6): 1–4. https://www.wired.com/2006/06/crowds/.

Hsueh, Pei-Yun, Prem Melville, and Vikas Sindhwani. 2009. “Data Quality from Crowdsourcing: A Study of Annotation Selection Criteria.” In *Proceedings of the NAACL HLT 2009 Workshop on Active Learning for Natural Language Processing*, , 27–35. http://dl.acm.org/citation.cfm?id=1564131.1564137.

Interplay-sports. 2017. “Interplay-Sports.” http://www.interplay-sports.com (June 30, 2018).

Liu, Hongyou, Will Hopkins, A Miguel Gómez, and S Javier Molinuevo. 2013. “Inter-Operator Reliability of Live Football Match Statistics from OPTA Sportsdata.” *International Journal of Performance Analysis in Sport* 13(3): 803–21.

Longomatch. 2011. “LongoMatch: Sports Video Analysis.” http://www.longomatch.org/documentation/ (June 30, 2018).

Müller, Oliver, Alexander Simons, and Markus Weinmann. 2017. “Beyond Crowd Judgments: Data-Driven Estimation of Market Value in Association Football.”

European Journal of Operational Research 263(2): 611–24. http://www.sciencedirect.com/science/article/pii/S0377221717304332.

Nowak, Stefanie, and Stefan Rüger. 2010. "How Reliable Are Annotations via Crowdsourcing: A Study About Inter-Annotator Agreement for Multi-Label Image Annotation." In *Proceedings of the International Conference on Multimedia Information Retrieval*, 557–66. http://doi.acm.org/10.1145/1743384.1743478.

OPTAsports. 2018. "OPTAsports Web Site." https://www.optasports.com (June 30, 2018).

Pastor-Vicedo, Juan Carlos, Onofre Contreras-Jordán, and Alejandro Prieto-Ayuso. 2017. "Performance Indicators as a Resource for the Selection of Talented Football Players." *Journal of Human Sport and Exercise* 12(3proc): S797–806.

Perin, Charles, Romain Vuillemot, and Jean-Daniel Fekete. 2013. "Real-Time Crowdsourcing of Detailed Soccer Data. What's the Score?" In *Proceedings of the 1st Workshop on Sports Data Visualization*, , 18–23.

Pettersen, Svein Arne et al. 2014. "Soccer Video and Player Position Dataset." In *Proceedings of the 5th ACM Multimedia Systems Conference*, MMSys '14, , 18–23. http://home.ifi.uio.no/paalh/dataset/alfheim/.

Rein, Robert, and Daniel Memmerte. 2016. "Big Data and Tactical Analysis in Elite Soccer: Future Challenges and Opportunities for Sports Science." *SpringerPlus* 5(1): 1410.

SAP News Center. 2017. "Get the Play-by-Play on SAP Sports One." https://www.sap.com/products/sports-one.html (June 30, 2018).

STATsports. 2018. "STATsports Web Site." http://statsports.com (June 30, 2018).

Stenhaug, Magnus, Yang Yang, Cathal Gurrin, and Dag Johansen. 2014. "Muithu: A Touch-Based Annotation Interface for Activity Logging in the Norwegian Premier League." In *MultiMedia Modeling*, , 365–68.

Sulser, Fabio, Ivan Giangreco, and Heiko Schuldt. 2014. "Crowd-Based Semantic Event Detection and Video Annotation for Sports Videos." In *Proceedings of the International Workshop on Crowdsourcing for Multimedia (CrowdMM '14)*, , 63–68.

Zhao, Yuxiang, and Qinghua Zhu. 2014. "Evaluation on Crowdsourcing Research: Current Status and Future Direction." *Information Systems Frontiers* 16(3): 417–34. https://doi.org/10.1007/s10796-012-9350-4.