SIDANE: Towards the Automatic Analysis of Football Tactics and Actions

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Abstract: In recent years technology has been used as an engine to improve the performance of the players and the preparation offered by trainers in a great variety of sports. In some of them, such as football, technology has contributed enormously to improving monitoring of players so as to assess their performance and to prepare tactics and strategies that are so essential nowadays for making the difference, before facing a match. In this paper we present SIDANE, an expert system capable of detecting important situations in football, from a tactics point of view and assessing if the players involved took a good decision from the point of view of the trainer. The SIDANE reasoning engine uses Fuzzy Logic with the aim of tackling uncertainty and facilitating the definition of rules close to the way in which the trainer communicates with his or her players. In this way the distance between expert and machine is greatly narrowed. The results yielded show how powerful SIDANE is as a starting point for the automatic analysis of important situations in team sports.

1 INTRODUCTION

A few years ago the huge impact that technology has in the sporting world today seems unthinkable. If, for example, a famous retired tennis player were to check firsthand how Hawk-Eye technology can answer if the ball fell inside or outside the court, he or she would have wondered, why couldn't this have been done before? Indeed, the tentacles of technology have more than infiltrated into any type of sporting event, whether it be amateur or professional. From the most basic technology, such as, for example, the use of digital scoreboards to manage the state of the game, through to highly complex technological solutions, such as those that create behaviour models for the players with the aim of improving their performance, technology is an essential support in the sporting field. From a professional point of view, this support is reflected essentially from four perspectives, which coincide with the main roles adopted in a large part of the sports there are nowadays: i) player ii) trainer, iii) referee and iv) spectator.

Professional players use technology to improve their performance or to train more effectively. For example a javelin thrower can make use of a movement analysis system to study if the throwing angle used was the optimum one or not according to other important parameters such as, for example, his or her run up speed or wind resistance. A professional billiards player can use an Augmented Reality system (Azuma et al., 2001) which digitally draws the possible trajectory of the ball according to the cue direction. Moreover, all this is done before the ball is hit! Trainers benefit from automatic tools to find out the players statistics, such as, for example, the distance covered, or the number of passes successfully made in ball sports. Furthermore, digital boards are also habitually used to explain tactics and strategies that players must follow, thereby saving time with respect to more traditional alternatives.

From the point of view of the referee, technology has enormously facilitated the assessment of game rules thereby avoiding disputes between players and conflicts that arise after seeing a replay on TV of the problematic move. The aforementioned Hawk-Eye in tennis is a highly representative example. Photofinish in athletics or the use of computerized vision techniques to detect if a player is offside (behind the defence line) when playing football (see Figure 1) are other important examples. Finally, the spectator also benefits from technology since a highly widespread trend nowadays consists in superimposing digital information onto real sports pictures, with occasional use of Augmented Reality. For example, in sailing

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or American football, this approximation is used frequently.

The fruit of our labour presented in this article and named SIDANE focuses on the role of the football trainer. Essentially, the aim of SIDANE is to facilitate the work of these professionals via automatic analysis of situations in which the players become involved. However, SIDANE can easily be transferred to other team sports in which there are a ball to guide how the game develops.

Nowadays, professional football has developed in such a way that the concept of team has taken on, if possible, greater importance. Physical preparation of elite football players is very demanding and, although on a technical level a player may shine at specific moments, it is the team as a whole that makes the difference in championships and tournaments of a significant duration. In this way, the role of the trainer takes on special importance when facing matches and preparing both tactics and strategy for his or her players. To increase the possibility of success when facing these tasks, the trainers do not hesitate to use this new technology with the purpose of communicating their instructions to the players in the most practical and efficient way possible. From the technological support point of view, nowadays there are tools that are automatically capable of following a player at all times (D'Orazio and Leo, 2010), measure the distance covered (Barros et al., 2007), jot down the number of passes made in a match (Hughes and Franks, 2005), or even monitor the work profile of the player (Carling et al., 2008).

However, it would be desirable to have higher level behaviour analysis tools, that is, those that will study when a player behaves as he or she should when faced with a certain situation, in keeping with the tactical vision and the strategy of his or her trainer. A simple example in the football world could be the goal shot. In this context, a tool that will analyse when a player should take a goal shot could analyse factors such as the distance to the goal, the number of opponent players blocking the shot or even, if there is any unmarked teammate located in a better position to take a shot at goal. Nowadays, this type of information is extracted manually by making notes on the video recording while the match took place. In this way, the trainer can justify to his or her players when they do well and when not. Unfortunately, this task, normally carried out by the trainers support team, is very tedious and prone to errors.

This is the main driving force behind SIDANE, the expert system presented in this work whose aim is to accurately analyse the actions of football players. For this purpose, at the core of SIDANE, there

Figure 1: Offside automatic detection.

is a reasoning engine based on rules that determine how a player should ideally behave in given situations. The conventionality used in SIDANE is Fuzzy Logic (Zadeh, 1996), a multivalued logic that allows approximated reasoning to be carried out, using linguistic labels, instead of exact reasoning. In this way, rules can be established such as the following: if a player is surrounded by a certain number of opponent players, then he or she should pass the ball so as not to lose it. Fuzzy Logic allows the knowledge necessary for a software system to automatically analyse its input data, to be shown in a way that is very similar to how a human expert would do it. This is a highly important advantage when reducing the distance between people and machines.

The remainder of this article is structured in the following manner. In section 2 there is a description of a study of related work, with special emphasis on those proposals in which there is an attempt to carry out some kind of automatic analysis in the world of football. In section 3 there is a detailed discussion on what SIDANE consists of as an expert system, what is its architecture, how its reasoning engine works and what is the knowledge base that has been used as a starting point for reflecting the instructions given by the trainer. Then, in section 4 the experimental results obtained when assessing SIDANE are described. The article finishes with section 5, in which the conclusions arrived at are commented on and some future lines of work are presented.

2 RELATED WORK

The state of the art as regards automatic analysis of situations in the sporting field and, specifically, in football, has made plenty of progress in recent years. In this context, it is worth stressing the importance of the tracking process as this is fundamental for locating the players and the ball at every moment (Prince, 2012). This process is carried out by sophisticated

Computer Vision systems which analyse the different pictures or frames that make up the video and which are captured by a multitude of cameras, which are strategically placed on the football pitch. In this context, the authors T. D'Orazio y M. Leo made a complete review of the state of the art that the reader may consult (D'Orazio and Leo, 2010).

From a data obtaining point of view static cameras may be used or those used for broadcasting matches. For example, it is common enough to use fixed cameras whose fields of vision overlap (Xu et al., 2005). However, it is perfectly possible to use the broadcasting cameras themselves, such as discussed by M. Beetz et al (Beetz et al., 2005). These authors considered an artificial system used to analyse the 2006 World Cup matches with the purpose of positioning the players at all times. On this point, it must be emphasized that regardless of the data source, there are traditional problems that any algorithm must tackle, such as, for example the ever present occlusions or variations in the lighting sources. One work which is representative of an attempt to tackle this problem is proposed by S.H. Khatoonabadi and M. Rahmati (Khatoonabadi and Rahmati, 2009), where they considered an algorithm made up of different steps, from a lower to higher level of abstraction, so as to, finally, obtain the position of every player on the game field.

Another large branch of activities that revolves around the tracking process is concerned with the use of hardware devices as a common denominator, which are incorporated into the player itself or the ball, instead of analysing pictures. For example, it is possible to use miniscule transmitters to directly, and with little scope for error, obtain the position of the players (Rohmer et al., 2001). Essentially, this approach is closely linked to GPS systems.

From an architecture perspective this layer of tracking is used as a base for other layers that have a greater level of abstraction whose aim is a higher level analysis. Then, for example, the position of the players and that of the ball could be used to *feed* an intelligent algorithm which will automatically determine in which position of the game field the player is making most effort. Another more complex example could be based on an algorithm that automatically obtains the degree of pressure from the team that does not possess the ball at each moment. Essentially, the trainer of a football team can use this knowledge to improve the preparation of tactics and strategy for his or her team, thereby saving a great deal of time as regards the traditional alternative which consists of viewing videos and making commentaries manually.

A significant amount of researchers are interested in obtaining statistical data that allows the tactical information to be used by the trainers to be extrapolated so as to improve the performance of their team. For example, G. Zhu et al considered the concept of *added trajectory* to extract tactical information in situations in which a team has scored a goal (Zhu et al., 2007). Another large field of study revolves around the analysis of the individual skills of the players. In this context, an important item is possession of the ball, since, a priori, greater possession of the ball implies greater control of the game and, therefore, greater probability of winning. To minimize the manual work derived from this task, X. Yu et al put forward a semi-automatic system capable of calculating ball possession by each player from the information obtained from the television cameras (Yu et al., 2005). Other related work is discussed by P.S. Tsai et al, which is focused in this case on analysing the speed of the players during the game (Tsai et al., 2007).

Beyond this individual study, the system put forward by M. Beetz et al is worth mentioning, in which the real time video streaming analysis is considered in order to recognize activities and events (Beetz et al., 2005). This concept of *event* is especially important for the state of the art of this type of systems to make progress. With the work mentioned above, the system designed uses a reasoning engine based on first order logic to determine if a situation that was learnt previously has taken place in the match under analysis. For example, the authors comment on the examples of events the opportunity of *scoring a goal* or the situation in which a player is *under pressure*. The system maintains a series of rules that are *fired* to calculate the probability of each event handled by the situation occurring in relation to the real situation under analysis.

Other works related with the above approach are discussed in the literature (Miene et al., 2004), (Nair et al., 2004). Both work in this case with simulated data obtained from the famous competition Robocup[1], in which there are leagues both for physical robots and for virtual players which are simulated by means of sophisticated algorithms. It is worth emphasizing that in these works events such as the *average distance covered* or *possession* by each player to automatically analyse if a situation is to his or her advantage or not, are studied and detected. Another representative event, associated with automatical assessment of the *offside event*, is discussed by T. D'Orazio et al (D'Orazio et al., 2009). This work is orientated, however, to facilitating assistance to referees when assessing if there is an offside situation or not.

[1] http://www.robocup.org

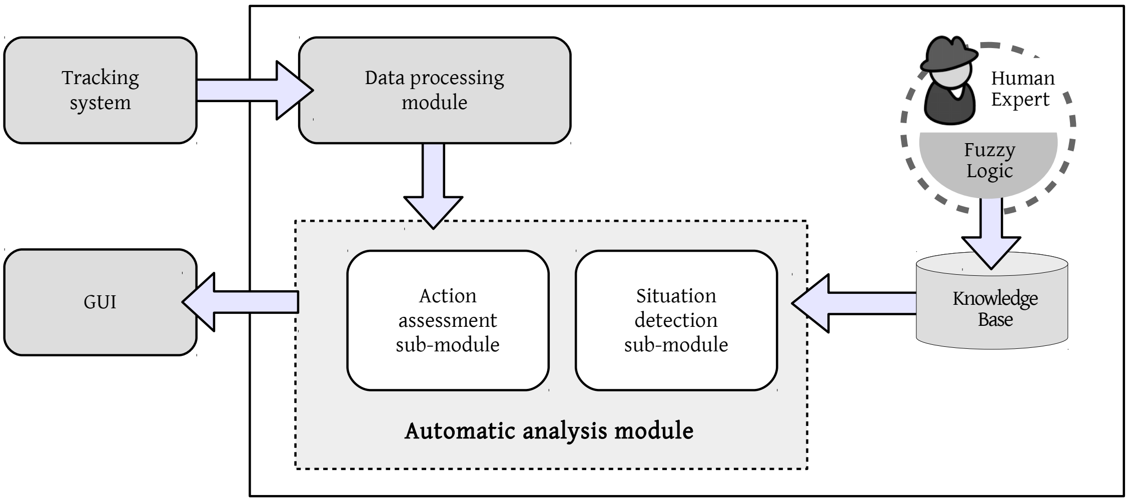


Figure 2: Architecture overview of SIDANE.

3 AUTOMATIC ANALYSIS OF EVENTS

3.1 Overview

SIDANE is an expert system for the analysis and automatic assessment of situations and events in the world of football. As will be discussed further on, SIDANE is capable of, for example, detecting when a player must pass the ball and when not. For this purpose, SIDANE makes use of an expert knowledge base, defined taking into account the instructions from the football trainer, and an inference system based on rules that determine when a player is behaving well and when not. Figure 2 graphically shows the SIDANE architecture taking into account the stream of information, that is, from obtaining raw data, using for, example cameras, until high level knowledge is created such as that commented upon in the previous example.

Initially, the *tracking system* is that responsible for obtaining the position of all the players and of the ball in the games area at every moment. In other words, the responsibility this system has could consist in transforming the video streams captured by the cameras into 3D information which shows the position of the players and the ball. The tracking system is outside the scope of this paper, but the SIDANE architecture has been designed to guarantee incorporation of any tracking system. Below, the *data processing module* normalizes the information relative to said positions, in such a way that they are all found to be in the range [0.0, 0.0, 0.0] and [1.0, 1.0, 1.0]. Moreover, this sub module stores all the information received by the tracking system in a database with the purpose of making, if necessary, a forensic analysis of the data stored.

The *automatic analysis module* is the real heart of SIDANE and is made up of a reasoning system capable of detecting and analysing interesting football situations from a tactical and strategical point of view. For this purpose, and as shown in figure 2, this module uses a previously defined knowledge base that houses a series of rules. These rules determine if the ideal behaviour of the football player is in accordance with the criteria of his or her trainer. The mathematical conventionality that sustains both the reasoning system and the knowledge base is Fuzzy Logic (Zadeh, 1996). Said conventionality is an extension of Boolean logic that allows dealing with uncertainty and vagueness of real world problems. For example, from a semantics point of view it is more practical to state that the ball is *close* to the goal than state that the ball is 1.34 metres from it. In the following section this conventionality will be studied in greater depth.

This behaviour analysis module encompasses, in turn, two other sub modules. The first of these is the *situations detection sub-module*, responsible for detecting what is happening in the game area. For example, the reader may think of the classical offside situation. The second sub-module is the *actions assessment sub-module*, responsible for assessing if the player took the right decision in accordance with that defined by the knowledge base and within the context of the previously detected situation. For example, the reader may consider the situation in which the central defence remains back, so offside does not apply and the forward of the opponent team is enabled to act.

Finally, SIDANE provides a user graphics interface that enormously facilitates the detection of errors made by the players and that, additionally, provides detailed information of their states at every moment. It is worth emphasizing that the SIDANE architecture has been designed with special consideration for scalability maintaining a high degree of independence among the modules inserted and defining some simple interfaces that enable other modules to be incorporated.

3.2 Knowledge Base and Reasoning Engine

Fuzzy Logic (Zadeh, 1996), put forward by professor Zadeh in 1965, has been the conventionality chosen as the focal point for SIDANE. Essentially, the main feature of Fuzzy Logic is it allows the quantification of imprecise values of our language, such as *much*, *little*, or *too much*, adapting itself better to real world problems than traditional logic, which only allows for two possible values: true (1) and false (0). In this context, the human brain has a great ability to interpret and solve complex situations without needing to handle numerical values. It is precisely from this consideration, that the *computing with words* stream arose, to which Fuzzy Logic adapts perfectly with the concepts of *linguistic variables* and *fuzzy rules*.

In the problem dealt with in this paper, a linguistic variable could be the *attitude* of the player which, in turn, could take the values of *defensive*, *neutral*, *offensive* and *very offensive*, for example. Subsequently, this variable could be used in a fuzzy rule of the type "IF the attitude of the player is very offensive AND the distance to the goal is short, THEN, make a goal shot". This knowledge definition model is significantly close to the expert in the domain, that is, the trainer, which drastically reduces the gap between the latter and the machine. In this paper the choice of Fuzzy Logic as a knowledge representation conventionality is complemented with the inference method of Mamdani (Mamdani, 1974). Essentially, this method is responsible for i) changing numerical values to fuzzy values, ii)making the reasoning process fuzzy and finally, iii) changing the fuzzy values obtained into numerical values that can be interpreted once again by a machine.

Figure 3 shows on the left hand side the fuzzy division of the game area into different areas according to two independent linguistic variables: X_Pos and Y_Pos. In this way, a forward that attacks the goal on the right will normally be situated in the values *Right* or *Very Right* of the Y_Pos variable, with less likelihood of retreating to defend and that, therefore, the Y_Pos variable takes values of *Medium*, *Left* or *Very Left*. This type of basic variables are the first level of the knowledge base defined in this paper. The definition of another example of a basic variable denominated *Attitude*, is shown in the upper right part of figure 3. Here, the possible values of said variable are *Defensive*, *Neutral* and *Offensive*.

The rules of the knowledge base of this first level are used to determine the occurrence of states or basic actions. Rules 3 and 4 of figure 3 show two basic examples. With rule 4, SIDANE is capable of inferring that if a player has possession of the ball and the number of opponents that are close to him or her is high, then the pressure level is high. The SIDANE knowledge base maintains more rules to determine the different pressure values according to if the number of close opponents is high or not. See how these type of rules are really simple to express for the trainer, which hugely facilitates their incorporation into the SIDANE fuzzy knowledge base.

Now pay attention to rule 10 shown equally in figure 3. This rule may seem more complex because the number of antecedents is greater, but in reality it is also rather simple. Rule 10, together with other similar rules included in the knowledge base, are used so that SIDANE infers when a player is found in an area of the field where it is suitable to make the so called *killer pass* and when not. This classic footballer move consists in passing the ball to a forward in such a way that the latter can score a goal just by pushing the ball. Obviously, this is a highly desirable situation. The rule in question assesses whether the one passing is lightly hugging a sideline and, moreover, is close to the rival goal. If this is the case, then the player is located in an area in which said pass is a desirable option.

The SIDANE knowledge base handles a second level or group of rules in which football concepts frequently worked on in football team training sessions are managed, such as for example *dangerous loss of ball*, *goal shot* or *long pass*. SIDANE is capable of automatically detecting when these situations take place and assessing if they were made at the right time or not. The actions associated with these concepts usually show yes or no type decisions, so defining them is simple. Figure 3 shows on the right hand side the definition of two variables associated with these actions: *killer pass* and *goal shot*. However, the most interesting part is in rule 16. This second level rule uses as an antecedent the information obtained by the first level rules (e.g. player situated in the *killer pass* area or *attitude* of the player) to determine if the player must carry out the *killer pass* or not. The example shows if the player has the ball, is in the

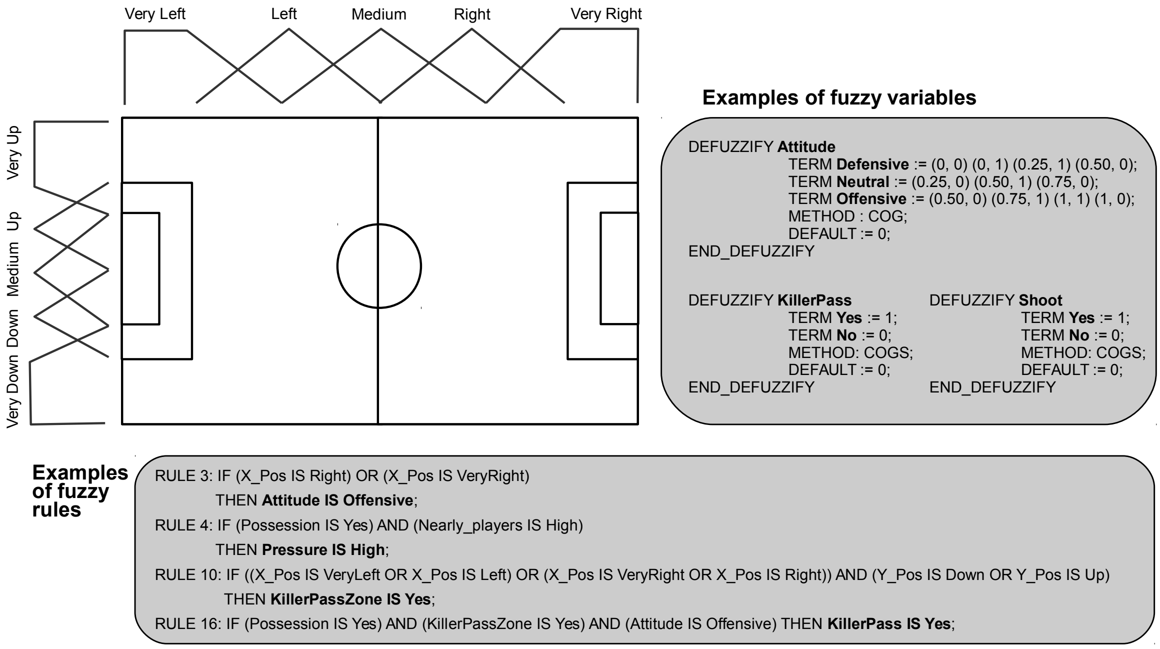


Figure 3: **Left**: Fuzzy division of the soccer field. **Right**: Examples of fuzzy variables. **Below**: Examples of fuzzy rules in the knowledge base. The adopted notation is related to the Fuzzy Control Language (FCL).

suitable position and his or her attitude is offensive, then he or she should make a pass that will potentially leave a teammate alone so the latter can score a goal. It is precisely in this type of rule where the essence of the expert system put forward in this work can be appreciated- SIDANE is capable of assessing if the decision taken was the correct one or not, considering the action of the player and the trainer criteria which is reflected in the SIDANE knowledge base.

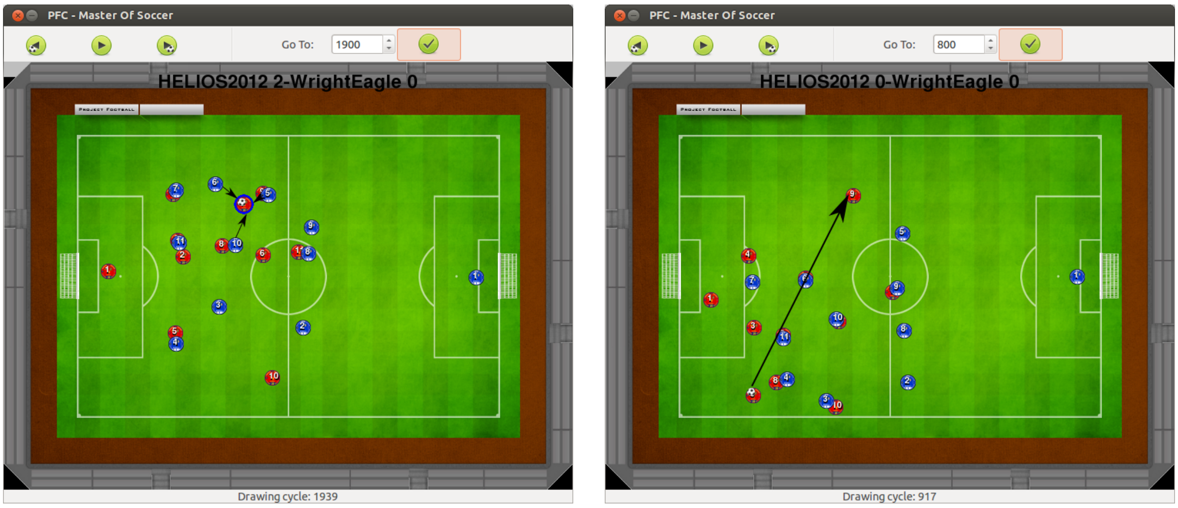
4 RESULTS

Our first aim for assessing the behaviour of SIDANE consisted in obtaining real football match data. Unfortunately, there is no public repository with the players tracking data and the research groups whom we contacted were not able to share theirs due to privacy laws. For this reason, in order to assess SIDANE we have used data from the RoboCup 2D Soccer Simulation League[2]. This league is a worldwide competition in which a range of teams of independent software agents compete to be crowned as the best. The software used in this competition allows tracking data to be obtained for all players and from the ball, so it is perfect to assess SIDANE. Likewise, the level of sophistication of the virtual players is so high that they behave as if they were real players. In this paper data has been used from the final of the RoboCup 2012 between the Helios (Japan) and WrightEagle (China) teams.

Figure 5 shows the number of detected and automatically assessed SIDANE situations. Specifically, these situations are the following: *area pass*, *dangerous loss of ball*, *killer pass* and, finally, *goal shot*. On this point it must be clarified that the *dangerous loss of ball* situation is that which triggers a counterattack by the rival team. In other words, it is a situation to be avoided by the team that possesses the ball. The *long pass* refers to a situation in which, for example, it is desirable to move the ball to the sideline opposite the game area in which, potentially, there are fewer opponent players and, therefore, more opportunities to advance.

Moreover, figure 4 shows two situations shown by the SIDANE graphic interface which allow what has been detected and what the players should have done to be viewed rapidly. Figure 4.a shows the red player in possession of the ball and a considerable number of opponent blue players surrounding him or her. In other words, SIDANE shot the rule in which there is a possibility of *dangerous loss of ball* by the other blue team. Here, the red player should pass the ball or throw it out of range of the other team to not lose it when faced with such a dangerous position. SIDANE detected and assessed 30 *dangerous loss of ball* sit-

[2]http://en.wikipedia.org/wiki/RoboCup 2D Soccer Simulation League



(a) (b)

Figure 4: **a)** Dangerous loss of ball detection. **b)** Desirable long pass situation.

uations in the test match. Another especially important situation from the trainer point of view is shown in figure 4.b. Here, it is desirable that the red player that has the ball makes a large run with the purpose of breathing some fresh air into the game and beginning the attack against the opponent goal. SIDANE is also capable of detecting and assessing these types of situations. In the test match, SIDANE detected and assessed 90 situations in which a long run was desirable.

Before discussing the conclusions and the future potential lines of work associated with SIDANE the reader is advised to see a video in which situations obtained from real matches are contrasted with situations analysed by SIDANE in the RoboCup 2D Soccer Simulation League. This video is available at *http://www.esi.uclm.es/www/dvallejo/sidane/video*.

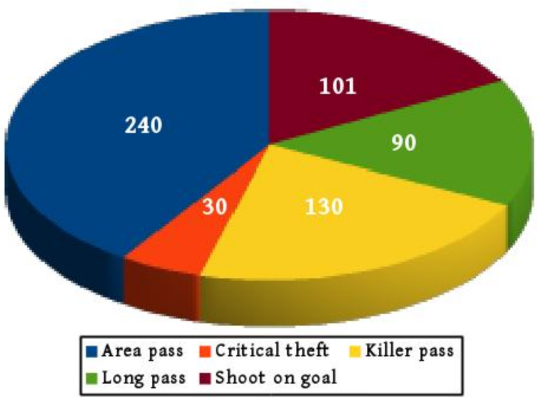


Figure 5: Detected and assessed situations by SIDANE in the RoboCup 2012 final.

When SIDANE detects and assesses a situation reflected in its knowledge base, the graphics interface marks the player involved with a blue circle, if the right decision is taken, or with a red circle if the wrong one is taken in accordance with that previously defined by the trainer in the knowledge base.

5 CONCLUSIONS AND FUTURE WORK

SIDANE is an expert system capable of automatically detecting and assessing essential situations from the point of view of the football trainer. Essentially, the main contribution this paper has made is in the use of expert knowledge to detect and assess high level situations and events in the football world. This consideration is a step forward with respect to the traditional techniques of note taking which is usually done manually and revolves around the trainers assistants watching videos to select the most important moves. To reach its objective, SIDANE has at its core a reasoning system based on Fuzzy Logic which makes use of a knowledge base made up of variables and rules that reflect the tactical and strategical criteria of a human expert or trainer. The use of If-Then rules greatly facilitate the modelling of said criteria and simplify their incorporation into the SIDANE knowledge base. Moreover, the SIDANE architecture has been designed to incorporate any tracking system and to extend its knowledge base with new rules associated with a great number of concepts and footballing situations.

To assess SIDANE we have used data obtained from the RoboCup 2D Soccer Simulation League, since it was possible to directly know the results of the tracking process of the players and of the ball at every moment. The analysis of a full match has allowed the identification of a large number of situations that revolve around concepts that are so essential from a tactical perspective such as the *area pass*, *dangerous loss of ball*, *killer pass*, *long pass* or *goal shot*.

Currently, our work is focused on detecting and assessing collaborative events in which various players are involved in the same situation. Specifically, one of the situations in which we are particularly interested is the *offside trap*, used by the defence of a team to leave the forward of the opponent team offside and, in this way, retake possession of the ball directly. Furthermore, we continue to search for data from real matches and hope that this paper contributes to us being able to carry out this task successfully.

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