Human vs. Robotic Soccer: How Far Are They? A Statistical Comparison

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Abstract. In soccer games, a performance indicator is defined as a selection of action variables that aims to define all aspects of accomplishment of the game goals. However their perception during the match is extremely difficult. Over the years, soccer has been used in many research areas including the robotic international soccer competition, RoboCup. The aim of this research project is to present a comparison study, performed to detect similarities between these two games (Human versus Robotic Simulation 2D soccer). Having an off-line automatic event detection tool as a base, a collection of final game statistics was done and the Mann-Whitney test was used to verify their statistical significance. The results show that the most frequent events occurred in both types of game are successful passes. In what concerns stopped game situation types, in both types of games, the most frequent one is the Throw in situation (Human-59,8%, versus Robotic-74,1%) and the less frequent is the Corner situation (Human-13,7%, versus Robotic-10,3%). Some differences still reside, especially in the frequency of set pieces and the action prior the goal.

Keywords: Soccer Game Analysis, Data Mining Algorithms, Robotics, Artificial Intelligence.

1 Introduction

Today, the game results in a game of soccer determine the success of the team. The coach tries to obtain helpful knowledge to create specific training situations, with the goal of increasing the teams competitiveness and improve its results[2]. In order to obtain good performance indicators to help soccer coaches in the detection of the trends of players and teams, the analysis system must be constituted by complex algorithms. These algorithms are normally developed by researchers in artificial intelligence (AI) area and tested in simple simulated

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environments, which usually enhance the interest of the researchers community. As one of the most popular and practiced sports in the world, soccer has been used in many research areas. RoboCup [5] is an international research project whose main objective is the promotion of AI and Intelligent Robotics. Basically, the research problem behind this project is the Robotic Soccer, where a number of distinct technologies are needed to construct a real or virtual Robotic team capable of playing a soccer game with a set of distinct rules. In this research work, we will focus only in the RoboCup simulation 2D league. This league is based in a system called soccerserver [8], which enables two teams of eleven players to play a soccer match in a simulated 2D environment. The system allows research in many different areas and many works appeared in several domains like flexible planning [12][13], intelligent communication systems [12][6] among others. The main goal of this research project is to measure the level of similarity between the soccer practiced by virtual Robots and Humans. To reach it, a soccer language was defined and subsequently used in software that was developed to calculate Robotic game statistics (number of passes, shots, goals, outsides, offsides) based on the log files of the 2d simulation league games. The analysis of the Human Soccer matches was based on audiovisual tapes and the data were registered on observation spreadsheets that have been developed for this project. The results, are based on the analysis of six games (three Robotics and three Human) corresponding to the latest Final Game competition. The remainder of this paper is organized as follows: Section 2 describes the methodologies used in this research work. Section 3 exposes the results achieved and finally in the last section a discussion is presented and final conclusions are presented.

2 Method

The human soccer data used in this study has been approved by a review board and the robotic data is available online (public domain-available at `http://ssl.robocup-federation.org/ftp/2d/log/`). In a soccer competition only the best teams, could reach the final game competition. In this research project, six games, corresponding to different tournament finals were selected in order to identify the similarities and differences between Robotic and Human Soccer. Regarding this goal, three Human Soccer Games (European 2004, 2008 and World Championship 2006 finals) and three Robotic Soccer Games (Robocup 2006, 2007 and 2008 finals) were chosen. In order to achieve the study objective, a set of soccer concepts were defined and a sequential analysis technique was used, to better characterize the game events. These concepts are represented in Table 1. The first definition presented in this soccer language is called a Kick. Generically, this event is based on the increase of the ball velocity. In this situation, many events could occur: a pass, a shot or even a goal. A successful pass occurs when a player kicks a ball and, after a finite interval of time, a teammate receives it. If an opponent player intercepts the ball, during this process, the event will be marked as an intercepted pass. In this project, a shot event was divided in three categories: a shot on target, an intercepted shot and a shot.

Table 1. Definition of the Generic Soccer Concepts

Generic Soccer Concept	Start Condition	Constraints	Final Condition
Kick	When a Player Increases the Ball Velocity Vector	Not Applicable	Not Applicable
Pass	When a Player Kicks the Ball	An Opponent Player does not Intercept the Ball	A Teammate receives the Ball
Shot	When a Player Kicks the Ball	An Opponent Player does not Intercept the Ball	The Ball Takes the Direction of the Goal Line
Goal	When a Player Kicks the Ball	The Ball does not Leave the Field	The Ball passes Through the Goal Line
Offside	When a Player Kicks the Ball	An Opponent Player does not Intercept the Ball	A Teammate that receives or is expected to receive the ball is not in a valid position

A shot on target occurs when a player kicks the ball in the goal direction. On the other hand, if the ball does not have the goal direction and left the field, this event will be marked as a shot. Finally if, after a shot on target or a shot, an opponent player intercepts the ball, this event will be selected as a intercepted shot. The other two events are directly based on FIFA rules. Concerning the offside rule, sometimes in soccer matches, when an offside situation occurs, if a player of the opponent team captures the ball, the referee, normally does not interrupt the game to mark the offside. In our project this situation was classified as an intercepted offside. Regarding the detecting of this set of events, two tools were used according to the different realities.

Robotic Soccer. Using the Robocup 2d simulation league log files as a base, a tool capable to automatically calculate the final game statistics was developed. The log files were produced by the soccerserver at the end of every Robotic game and contained detailed information regarding the game, such as position of the players and the ball in the field in each cycle or players stamina, among others. In this work, to calculate the final game statistics, only the information related to the players and ball position were used. The Robotic game in the 2d simulation league presents some differences when compared to Human Soccer. Each game is composed by 6000 cycles, there were no differences in the field characteristics that could influence the way of play and the teams always attack for the same side. Attending to these particularities, and to perform a sequential game analysis, a vector was constructed. Each vector position is designated as a scene and corresponds to one game cycle. Each position has information concerning players and ball position, etc. After breaking the game into a vector structure, a detection event algorithm will analyze it, starting with the detection of the kick events.Once this first analysis is done, the algorithm will try to identify the game events that happened in the match according to the start conditions specified in Table 1.

Human Soccer. From the DVDs with the Human Soccer Games, a spreadsheet was created in order to classify the different events of the games using a method of observation. The main features that this tool supports are: identify all players that participated in the match, the different set of events, the duration of the event and finally, filter all events by time. This spreadsheet is capable to display, at the end of the monitoring process, the final game statistics.

Data Analysis. All data was analyzed using Microsoft Excel 2007 with a specific statistic package- Analyse-it version 2.20 (available at `http://www.analyse-it.com/blog/2009/5/analyse-it-2-20-released.aspx`). To perform the comparison between quantitative variables a non-parametric test, Mann-Whitney test, was used and the level of statistical significance was set at $p<0.05$.

3 Results

When the final game statistics (Table 2) are evaluated, in what concerns to passes ($U=21.5$ $p<0.01$), in the Human Soccer the successful passes represents almost 80% of the total executed in the game (with 22% of missed passes). Comparing to the Robotic passes reality, where the number of successful passes is lower than 66% and the missed ones are higher than in Human Soccer. However, the successful passes are the most frequent event in both realities. In the shots area, there were also statistical differences between these two realities ($U=86,5$ $p<0.01$) with the predominance of the shot on target (69,5% for Human and 47,6% for Robotic respectively). In the outsides group (Goal Kick, Corner and Throw-In) the most often event is the Throw-in. This particular situation is more frequent in Robotic soccer, but the other two considered events (Goal Kick and Corner) occur more in Human Games ($U=48,5$ $p<0.01$).

Table 2. Generic Comparison between Human versus Robotic Soccer

		Human Soccer			Robotic Soccer		
Groups	**Final Game Statistics**	**Average per Game**	**Standard Deviation**	**Percentage**	**Average per Game**	**Standard Deviation**	**Percentage**
Pass	Sucessfull Pass	544	117,9	77,9%	176,3	48,8	65,9%
	Missed Pass	154,3	21,3	22,1%	91	20,6	34,1%
Shots	Shot on Target	17,3	1,6	69,55%	3,3	0,5	47,6%
	Shot	2,7	0,5	11,64%	1,3	0,9	19,1%
	Intercepted Shot	4,3	1,7	18,81%	2,3	0,5	33,3%
Not Applicable	Goal	1	0,5	100%	2,1	1,2	100%
Offside	Offside	6,6	2,4	100%	1,6	0,8	18,76%
	Intercepted Offside	0	0	0%	4,3	1,2	81,24%
Outside	Goal Kick	17,4	2,4	26,37%	3,9	1,6	15,6%
	Corner	9,1	1,6	13,76%	2,3	1,4	10,3%
	Throw-in	39,3	5,7	59,87%	14,8	5,4	74,1%

3.1 Goal View

Doing a more careful examination of the goal event, and starting with the analysis of the goal scoring in a time-basis of half games it is relevant to note that 75% or more of the goals in both scenarios were scored in the first half of the match and only 25% or less were scored in the second half of the game (Figure 1) (U=19.5 p>0.05). If the period of the match that contains the most goals (the 1st half) is divided in thirds of half, it is visible that goals scored by Robotic teams happen mostly in the first and second parts (more than 80% of the total amount of goals were scored in these two periods), while in Human Soccer this is not true (Figure 2). Observing the type of offense during the scored goals (Figure 3) it was detected that the Human and Robotic worlds have antagonistic behaviors (U=44.5 p>0.05). In the Robotic scenario, the offense style that more often allowed scoring a goal was the counter-attack situation (60% of the total), while in the Human reality was the set pieces (75% of the total situations). In the three Human Soccer Games, no goal was scored in a counter attack situation. The other offense situation (organized offense) corresponds to 25% and 20% of the total scored goals in Human and Robotic realities respectively. In the Robotic competition, all goals resulted from "combination play" (Figure 4), contrarily to Human Soccer, where the goals resulted from different situations: Direct Shot (25%), Combination Play (25%) and Long Pass (50%). These differences, however are not statistically significant (U=101,5 p>0,05). These actions prior to the goal interfere with the frequency of the Set piece observed in the two realities (in this work a a set pieces occurs in the game when, after a Throw-in, Goal Kick or a Corner situation being detected, a pass combination between teammates (always involving four players or less) is performed and the time spent by the team to achieve the penalty area is relatively short (depending of the field area). It is not strange that in Robotic Soccer only the Throw-in was observed and it constitutes only 30% of the total scored goals. In Human Soccer, 53,3% of the goals were preceded by a Corner-Kick and 26,6% by a Penalty situation (Figure 5). The area of the field from where the offensive attempt was materialized was recorded and the findings indicate similarities between the two realities (U=38.0 p>0.05). In the Robotic world 80% of the goals

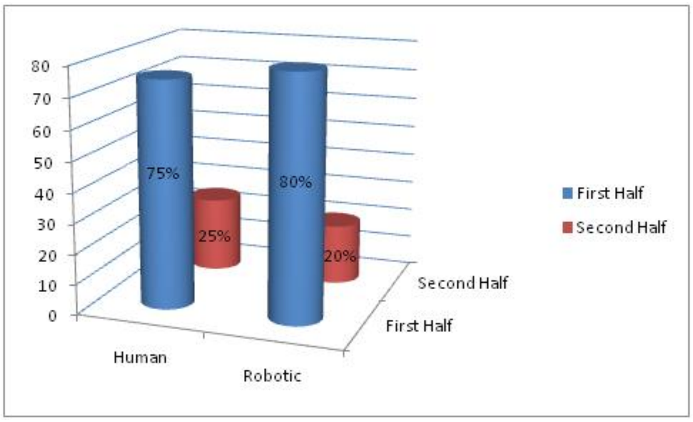

Fig. 1. Frequency of scoring by period of time (first and second half) and by reality

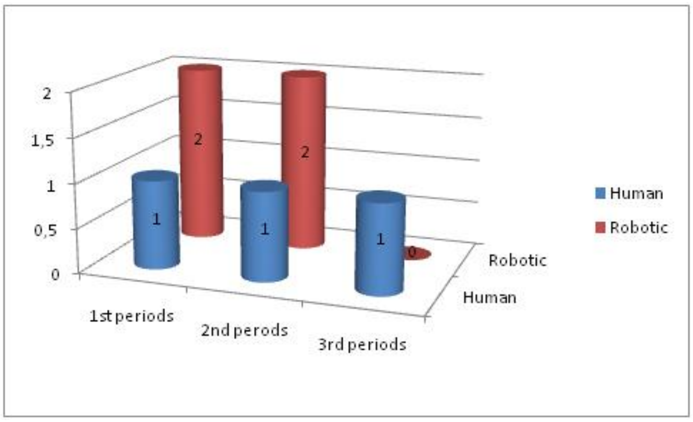

Fig. 2. Frequency of scoring by thirds of half and reality

were scored from the Penalty Area, and in the Human Soccer, all scored goals were from inside of the Penalty Area (50% from the Penalty Area and the other 50% from the Goal Area) (Figure 6).

3.2 Final Game View

Conducting now a more detailed analysis of each game, we started by analyzing the Human games. We observed that two of them ended in the regular time period, with only a goal scored (2004 and 2008 finals) and only one game (2006 final) ended in the penalties session. In what concerns to the executed passes in the regular time of the matches it is easy to note that, all over the years, the frequency of successful passes increased and the opposite was verified in the missed passes (Figure 7). Having only the passes as comparison criteria, we concluded that the most balanced final match was the 2006 final, and, curiously, this game was also the only one that needed extra time to find the winner. In the 2004 final, the winning team had less successful passes executed (171 versus 216) and in 2008 the winning team also presents less successful passes executed (318 versus 353), when compared to their opponent. However, in this final case, the successful passes of the Spanish Team constituted more than 84% of the total executed against 83% of their opponent, unlike the 2004 final game.If the analysis focuses on other statistics such as Shot (Figure 8), in the two first games the results show that the winning teams had less shots (almost in the three types) against their opponents but still won the games. However, in the third analyzed game, the winning team (Spain) had almost four times more shot on target events against Germany and, in the other type of shots only on the intercepted shot did these two teams present equivalent values. Making the same analysis for the RoboCup, and starting with the pass reality (Figure 7), the game where a more prominent difference between the two teams is verified is the 2007 final. This match was also the only one that did not need extra time to find the winner. Doing a parallel with the 2004 Human final game, a similar fact

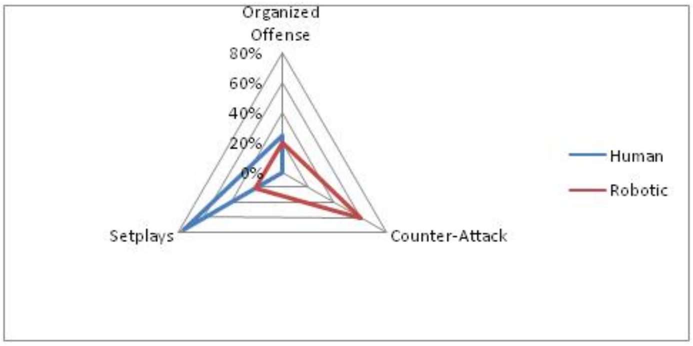

Fig. 3. Type of offense style used to score a goal by reality

happened: the winner team needed to do less successful passes compared to their opponent. In the other two games, the teams obtained similar values turning this factor into a balance indicator between the teams. Over the years, there were not many differences in terms of shot statistics in the Robotic games (Figure 8). A possible explanation for this is that these teams did not do many shots in the game. Although, the number of shots was in average similar in the two compared realities, the other two types of shots show very different frequencies.

4 Discussion

With this project work, we can conclude that Human soccer is more competitive, when compared with the Robotic one. This evaluation is sustainable by the presence of six different teams in three consecutive Human finals, compared to only two teams in the other reality. In a first instance, this fact could be explained by the rules of the Human soccer competitions. When a European Championship occurs, many powerful National Teams in this sport like Brazil, cannot participate in this competition. However, in the final games used in this work, only European Teams participated, even in the 2006 World Championship Final, which means that in the recent years the European Teams were better than the others. In what concerns to RoboCup, the official numbers show that the number of participants has increased every years, and therefore the presence of the same two teams in three consecutive finals can be explained by the fact that these teams have achieved, over the years, high performance levels, making it difficult for any younger teams to compete against them. In terms of game rules, some differences were detected in these two realities. In the extra time period, in the Robotic environment, the game immediately ends if a team scores a goal. In the Human reality this rule has been eliminated in international competitions since the World Cup 2002. In what concerns to the penalty shootout section and, in order to increase the research challenge, in the Robotic competition a rule from the ice Hockey and 7th soccer was used which consists in shooting the ball not in the eleven meters mark, but allowing the marker player will has

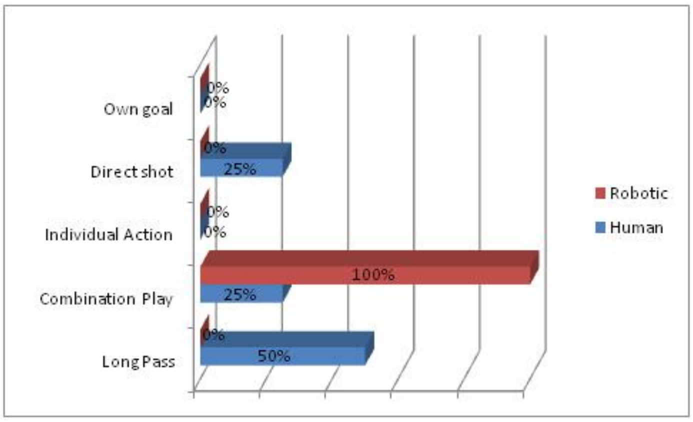

Fig. 4. Action prior to goal by reality

the freedom to lead the ball from the midfield and to shot from it in any field region. Over the years, many were the researchers that have tried to evaluate the development of Human Soccer, focusing their studies in goal characteristics [2]. In order to do a higher level comparison between the two treated realities a parallel with some research works will be produced. In 1968 Reep and Benjamin [10] analyzed more than 3000 matches and concluded that approximately 80% of all goals resulted from a sequence of three passes or less and a goal is scored every 10 shots. Although this study seems to be dated, in the past few years many were the studies that confirm these findings using different FIFA World Cup finals [3]. In our research games, the teams scored 9 goals (4 in the Human games and 5 in the Robotic games) and 66, 7% of them resulted from a sequence of three passes or less. Also, if the analysis splits the two realities, the conclusions show that 75% of Human scored goals resulted from a sequence of two passes or less (usually in set pieces), against 60% for the Robotic reality. For the second finding from Reep and Benjamin, and if the shot definition covers the three defined types, none of the games confirms the theory. In the Robotic scenario, only 2 of 3 games had goals and in these particular matches, the teams only need 9 shots to score 2 goals (2006 final) and in another match only 8 shots are needed to score 3 goals (2007 final). From the Human perspective, in the 2004 final, only one goal was scored and 27 shots were counted; in the 2006, final 19 shots were counted, and 2 goals scored and finally, in the 2008 final, 23 shots were counted and only 1 goal scored. Even if the definition of the shot used by Reep only covered the shot and shot on target or only the shot target, the extracted results would still not confirm his theory. Continuing analyzing the goals and its characteristics, over the years many were the studies that aggregated the goal scoring in reference to time of accomplishment supporting that the frequency of goal scoring is time dependent. The results produced in our research work show that the highest percentage of goal scoring, in both realities, happened in the first half of the game. However when the match was divided

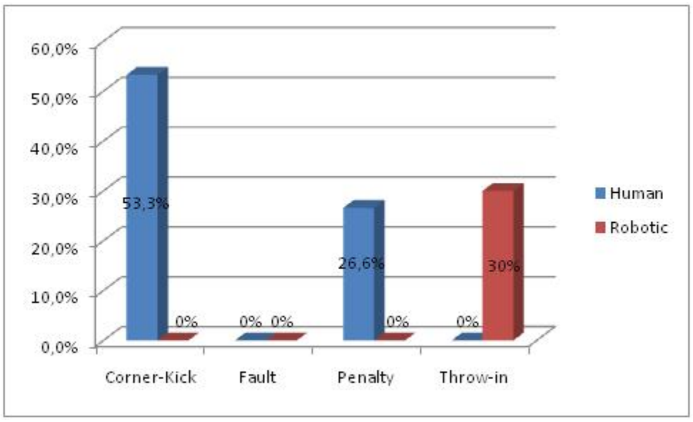

Fig. 5. Frequency of set pieces types

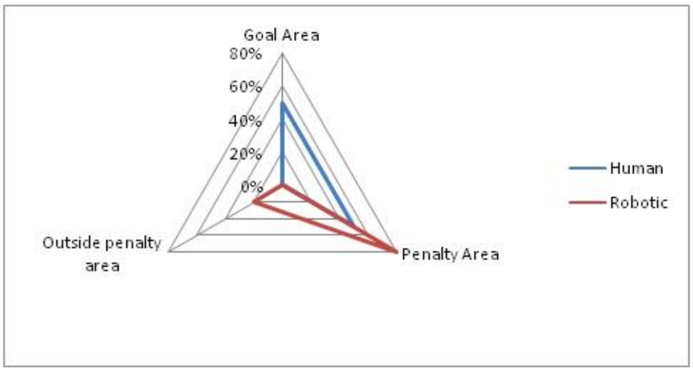

Fig. 6. Area from which the goals were scored

in 15 min periods, the results show a correlation between the 2 first periods (in the first half) in the Robotic environment. On the other hand, in the Human world, the results did not show any type of correlation between 15 min periods and scored goals. Although many studies demonstrated that, at the end of the games, the performance of the teams drop because of the greater deterioration in physical condition, and sometimes the losing team takes some risks, pushing players forward, trying to create goal opportunities, conceding not often further goals [11]. Others are that did not find a correlation between goals and time period like ours [7]. Regarding the type of offense during goals, a database was constituted, from the 1982 Tournament by Piecniczk [9] that concluded that 27% of the goals were resultant of a quick offense and only 28% were through organized offensive actions. From the 1990 World Cup Tournament Dufour [1] concluded that this trend had inverted: 88% of the goals came from an organized

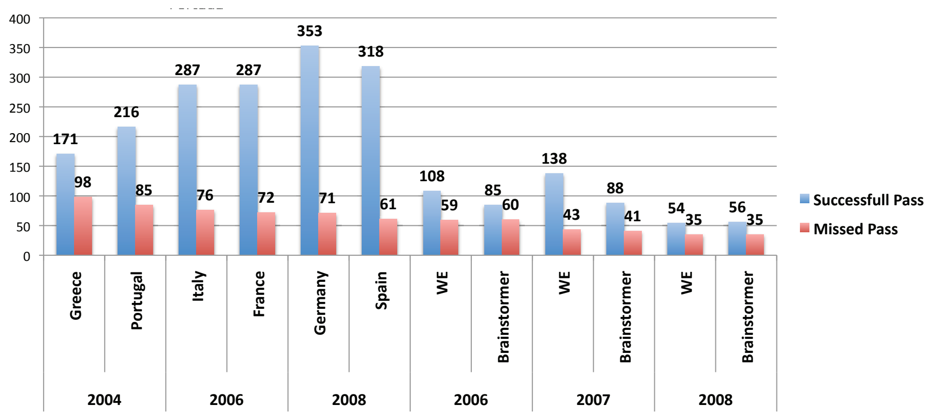

Fig. 7. Pass Statistic in Human and Robotic Game Fnals by match

offense and 12% from a strike offense. Nowadays, the execution of set pieces constitutes an import part of a team tactics as well as in the outcome of a game. Like our study, many others claim that more than 1/3 of the scored goals in many competitions resulted from set pieces [2]. On the other hand, we observed that, in the Robotic world, the most used movement to score goals was the counter attack (60% of the total scored goals). Examining the actions that lead to the goal, our findings show that in Robotic world all process resulted from a combination plays (100%). In the Human environment the results were a bit different. The long passes represent the highest percentage of cases (50%) followed by direct shot (25%) and combination play (25%). Doing a parallel with the scientific literature the findings were similar to the results obtained in the Human game finals. The long passes represent the highest percentage (more than 34%) followed by the combination play (29,3%) and individual actions (17,1%) [14]. Analyzing the set pieces more common before the goal and, in consequence of the results previously explained; in the Robotic environment only 30% of the scored goals were preceded by a set pieces (Throw-in situation). In the other analyzed reality the most common set pieces was the Corner Kick (more than 57%), followed by the Penalty situation (more than 26%). However, the achieved results produced by some research works [4] present some different characteristics, indicating that, in spite of the corner Kick having a good percentage in terms of goals scored (27% and 24, 4% respectively, the most relevant set piece was the free-kick, which represent 37% and 39%, respectively. Another recent study [14] showed that the major set piece observed before the goals scored was the corner situation (40% followed by the free kick situation, with 30%). Although the comparison of these studies provides, to a certain point, dissimilar results, even in the Human final scenario, it is clear that the corner kick situations occupy a higher percentage of the produced goals. In the Robotic environment, the unique set piece before the goal was the throw in. In what concerns to the area where the final effort

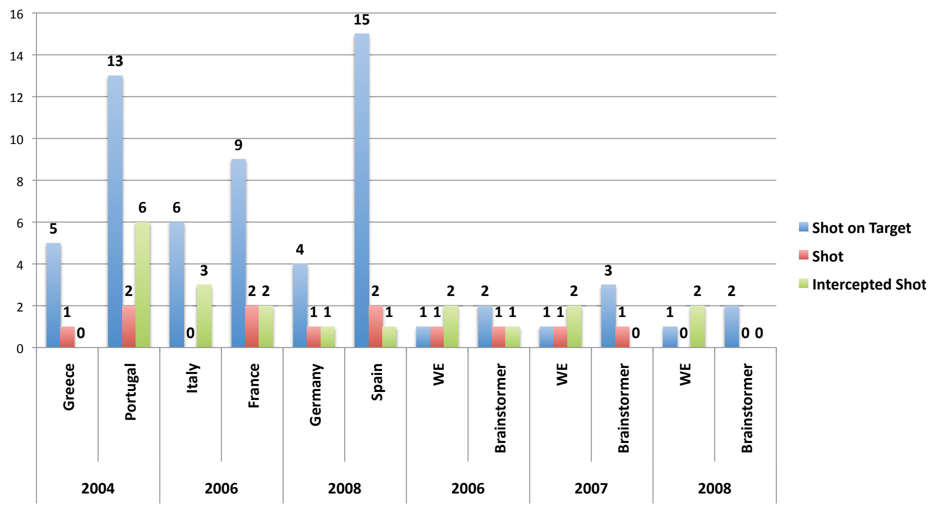

Fig. 8. Different Types of Shots in Human and Robotic Game Finals by match

was materialized, the findings of our research indicates that the majority of the Robotic goals were scored from inside the penalty box (80%). However, in the other observed reality the frequency was divided between the penalty area (50%) and the goal area (50%). In the literature, the results achieved were very similar to our study. In the 2002-03 Champions League season Michailidis [7] concluded that more than 64% of the goals were scored from inside the penalty area and 36, 5% from the goal area. Other studies, produced for instance by Dufour [1], indicated that 81,8% and 80% of goals were scored from inside the penalty area and 16% and 15% from the goal area, respectively. Summarizing, our study shows some similarities between the two realities analyzed in what concerns to the frequency of outside situation and also in the relation between successful and missed passes. The main differences still reside in the action prior the goal and the frequency of set pieces.

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