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A glyph and animation-based visualization system for evaluation and comparison of soccer players

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A GLYPH AND ANIMATION-BASED VISUALIZATION SYSTEM FOR EVALUATION AND COMPARISON OF SOCCER PLAYERS

by
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A Thesis

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Abstract

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A GLYPH AND ANIMATION-BASED VISUALIZATION SYSTEM FOR EVALUATION AND COMPARISON OF SOCCER PLAYERS
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The dimensionality of soccer statistics relating to both player and goalkeeper specific data can be difficult to interpret. Attempting to formulate an analysis of large sums of soccer statistics can be extremely challenging if the data is not presented graphically. As a result, we developed an application, titled Soccer Scoop, which provides two separate visualizations that can aid a soccer team manager. With this application, a team manager can compare two players on different teams, analyze a particular player before signing them to a contract, measure the performance of a particular player at different positions, generate practice exercises, and determine if a particular player plays better on the road or at home. Leveraging our existing statistical analytics tool, Soccer Scoop, we developed a goalkeeper visualization add-on that can also assist a team manager. With the goalkeeper visualization tool, a team manager can compare a single goalkeeper between two games, measure the overall performance of the goalkeeper both for games played at home or away, as well as to devise the appropriate training exercises needed to strengthen any visible weakness. The visualizations used in this application apply information visualization techniques, such as glyphs, modified star plots, details on demand, color, and gestalt principles.

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Chapter 1

Introduction

The interpretation and relation of data collected by team managers in the field of athletics, for purpose of developing pre-game objective scenarios such as tactical set plays, drills, or other player performance monitoring tasks, can be daunting considering the high dimensionality of the data. Managers of a team can gather data using many disparate methods that relate to specific player attributes such as speed, precision, or other performance values, however relating this data in a unified manner may be hard to achieve. The analysis of this data may be useful in determining the success or failure of a team or players as they progress, however with the high dimensional and disparate nature of most data collected in athletics, many team managers continue to ignore, hide, or inaccurately interpret data that would otherwise be beneficial if presented appropriately.

Our first step with introducing a solution to this dilemma is called Soccer Scoop, a visualization tool that fulfills the need for player-to-player comparisons relating to team performance and dynamics by providing a metaphorically unique way to visualize and interpret data [1]. With Soccer Scoop we used a variety of natural field elements to represent several data categories that cross reference specific key player elements and allowed for the quick visualization of data. The overall goal achieved was to create a metaphor-based data visualization [2], [3] that was appealing to the manager of the team thus minimizing overall cognitive effort surrounding team player and attribute analysis. Soccer Scoop consists of two separate and very unique visualizations for soccer. The first visualization, called Field Viewer (see Figure 2.1), shows the user vital information

about one player. This visualization represents the player's attributes in the form of a soccer field and with various entities on it. The second visualization is called the Player Viewer (see Figure 2.7). The user is able to compare two players with this visualization, as each player is color coded [4] to show the player's effectiveness in a given category.

From a team manager's perspective, he or she wants to be able to generate practice exercises for a particular player based on their weaknesses, compare two players on different teams, evaluate the strengths and weaknesses of a player before signing them to a contract, determine if a player plays better on the road or at home, or determine what the best position is for a particular player. Team managers need answers to these questions on a daily basis, as a team manager is always looking to improve their roster. Providing effective visualizations, such as the ones included in Soccer Scoop, will lead to team managers making more intelligent decisions.

For data integration with our visualization, the user is required to create and load a CSV (Comma Separated Values) file based on a XLS (Microsoft Excel) field data template that is provided into the program before viewing either visualization.

The user is able to toggle between the both the Field Viewer and Player Viewer visualizations as well. Toggling between both visualizations is as easy as clicking on the appropriate viewer button as available above each visualization.

Both the Field Viewer and Player viewer visualizations allow for single player analysis of a specific team, however the Player viewer adds a two player comparison between teams. Such will empower a team manager to make comparative analysis regarding fine grain player characteristics [5] which may also assist with the coaching in

the development of a tactical set play or other globally team centric decisions crucial for overall team success.

In the chapter that follows we show that Soccer Scoop was designed with an extremely intuitive interface [6]. All the important player characteristics have been uniquely incorporated within the visualizations. Also the uniqueness of their placement allows for the player characteristics to be quickly interpreted. This allows for a system that can be easily adopted by any user or team manager regardless of their level of technical experience.

Although Soccer Scoop solves the problem for analysis of data for players specific to various field positions within the game of soccer, it does not provide a visualization for the data as related to the goalkeeper position. In the game of soccer, the goalkeeper is one of the most important soccer players on the field. This is due to the fact that they tend to be the first line of attack and the last line of defense which means that they must make quick decisions in how to save and return the ball to the players in the field. It is the goalkeeper that will ultimately determine the outcome of a particular game. Their skills tend to be focused on techniques such as footwork and the abilities of deflection, catching, or throwing of the ball. To further enhance the data and analytics capabilities of the Soccer Scoop application, we developed the goalkeeper visualization that allows for managers of a team to view soccer goalkeeper specific performance attributes. The goalkeeper visualization application presents a single visualization that maintains similar metaphoric and usability characteristics established within our Soccer Scoop application. Leveraging similar visual cues and appealing visual styles allows for team managers to adapt easily to the goalkeeper visualization without the need to learn an entirely new tool.

The goalkeeper visualization is called the Goalie Viewer (see Figure 3.1) and shows vital statistics based on the attribute data (Precision, Fluency, Rapidity, etc.) of a single player. Additionally, the goalkeeper visualization allows for the comparison of the vital statistics based on attribute data of the individual player with other games in which they have played, as well as a comparison of two different characteristics for the same goalkeeper for the same games. It can also allow for the comparison of different goalkeepers on other teams for the same game or between different games. The visualization represents the goalkeeper's attributes as an actual soccer goal with various data entities adorned throughout.

In the view of a team manager, it is necessary to be able to generate practice exercises that are centric around that of a goalkeeper for specific performance deficiencies, compare this player with themselves or another player between games in order to determine if the goalkeeper is suited better at home or on the road, or perhaps evaluate the player as a goalkeeper before signing them into a contractual agreement. It is necessary that a team manager establish answers to these questions throughout daily practices in order to gain better insight with the overall progress or performance of their goalkeepers to improve their team's roster and chances for success in future games. Providing an effective way to visualize specific goalkeeper data using the Goalie Viewer will ultimately guide team managers to the path of success through intelligent decisions.

Integrating field data into the Goalie Viewer is achieved by means of form field input within the main Soccer Scoop application before accessing the goalkeeper visualization.

Since the goalkeeper visualization is integrated with the original Soccer Scoop visualization application, the user is able to toggle between the various available

visualizations, including the Goalie Viewer. Toggling between the other visualizations and the newly developed Goalie Viewer visualization is performed by clicking on the appropriate view button as available within the application, a technique which facilitates easy transitions between visualizations within the same tool [7].

Our Goalie Viewer was designed to be as unique, intuitive, and innovative as possible, however a future user evaluation is recommended in order to prove this. Like the Field Viewer and Player Viewer, the design allows for the presentation of all goalkeeper attributes and key elements associated with performance. These design qualities may allow for even the most technically deficient team managers to quickly adopt the system.

1.1 Related Software

Currently there exists several visualization tools that allow for the simulation of pre-game training initiatives for play-by-play analysis: "Grass Roots Coaching" [8] is a drill viewer visualization tool that encompasses the overall sequences of play drills related to both offense and defense, and "TactFOOT: Soccer Coaching Tactical Software" [9] is a visualization tool that allows for the creation of training exercises and drills through simulation animations. The need for coaching within the realm of tactical field dynamics between plays is surely met with all that is currently available, however analysis tools for player-to-player comparisons is almost nonexistent in the tools described above and extremely hard to find. When considering goalkeeping, these tools assist team managers with simulation and development of coaching techniques for any position, including goalkeeping; however none of these tools possess the feature of

gathering actual field data of an individual player (including goalkeeper) for use in a future analysis.

1.2 Contributions and Outline

The major contributions of this thesis are as follows. First it presents a set of visualization tools called Soccer Scoop (Field Viewer and Player Viewer) that allow for the analysis of soccer player performance statistics by generating an intuitive visualization based on data collected by coaches. We then explore the functionality of Soccer Scoop by outlining three case studies over a period of five games (home and away) that were developed and observed with the use of actual field data of ten players of the University of Craiova soccer team from the Romanian soccer championship. The second part is a visualization tool called Goalie Viewer that allows for the analysis of goalkeeper specific performance statistics by coaches and similarly generates an easy to understand visualization. We then explore the overall functionality of our goalkeeper visualization by presenting several case studies based on observations over a fifteen game period that use data of a single goalkeeper of a second division University of Craiova team from Romanian soccer championship. Third, several animation principles are applied to our visualization tools as an enhancement to the overall effectiveness in representing data relating to the various player performance attributes. For the fourth part, we outline and recommend a user evaluation setup for a future case study that has not yet been performed. An emerging research method called a Multi-dimensional in-depth Long-Term Case study (MILCs) is used only as a basis for a proposed user evaluation setup at which is designed to possibly prove the validity of the usefulness and

effectiveness of our visualization tools. The last part concludes with some future work relating other enhancements to our visualization tools such as the development of real-time data interface methods, applications of our tools within the field of Sports Medicine, and the possibility of mobile-based implementations.

The remainder of this thesis will follow the outline as described below:

- Chapter 2 discusses a visualization tool for soccer player specific performance and statistical analysis.
- Chapter 3 discusses a metaphor-based visualization tool for goalkeeper specific performance analysis
- Chapter 4 describes several animation principles that have been added to the visualizations in order to enhance their effectiveness.
- Chapter 5 outlines a proposed user evaluation setup recommended for a future case study in order to prove the effectiveness of our developed visualization tools.
- Finally, Chapter 6 provides a summary of the work presented within this thesis and identifies the possibility of some additional future work.

Chapter 2

Visualization for Soccer Player

In this chapter we present a solution[1,2,3] for soccer player analysis; both for distinct player dynamics and player-to-player comparisons. Our solution, called Soccer Scoop, is made up of two distinct visualizations called the Player Viewer and Field Viewer. The overall dynamics of a specific player are represented by a specific structure of data elements that were provided and used to model the requested visualization. It was hoped that three main data aspects with respective data attributes could be used to observe the overall offensive and defensive characteristics, enabling a determination of the current skill level, and thus allowing for an overall focus onto any variables that may otherwise remain transparent; hindering any growth for a player or the team.

The solution classifies the provided data structure into three main categories: execution mechanics, tactical utility, and frequent mistakes in execution (see Table 1 below).

[1] This chapter is primarily derived from a publication at the 14th International Conference on Information Visualization (IV 2010) in collaboration with Adrian Rusu, Doru Stoica, Benjamin Hample, Kevin McGarry, and Robert Russell [1].

[2] This chapter was featured in the Press of Atlantic City [10].

[3] This chapter was featured on ABC Channel 6 News.

Table 1. *This matrix is used to collect data of a single player during a game. The data can then be entered into a database and read into the application.*

			KICK			HEAD BALL	THROW IN	TRAP	TACKLING	DRIBBLING	FOOTWORK	BALL PROTECTION
			total	unsuccessful	%							
Execution Mechanics	Precision	L	0	0	0.00 %	B	C	D	E	F	G	H
		M	6	3	50%	64%	100%	76%	33%	68 sec	61,4 %	55%
		S	13	13	100%							
	Fluency		L 4			L 3	L 3	L 3	L 2	L 3	L 2	L 3
	Coordination		L 3			L 3	L 3	L 3	L 3	L 3	L 3	L 3
	Easiness		L 4			L 3	L 3	L 3	L 1	L 4	L 3	L 3
	Rapidity		L 4			L 3	L 2	L 3	L 2	L 4	L 3	L 3
Tactical Utility			I 9			J 0	K 14	M 21	N 0	O 428	P 0	R 8
Frequent mistakes in execution	Foot		S(L) 4			T(L) 0	U(L) 0	V(L) 0	X(L) 0	Y(L) 0	Z(L) 0	W(L) 1
	Torso		a(L) 3			b(L) 3	c(L) 2	d(L) 3	e(L) 3	f(L) 3	g(L) 3	h(L) 3
	Slow execution of movement		L 3			L 3	L 2.5	L 3	L 2.5	L 3	L 3	L 3

Before describing the data structure in detail, we should make mention that our provided data structure was used as a basis for the initial design of our tool and the standards set forth in this chapter, such as a 4-point Likert scale, category classification, and the use of specific attribute and element characteristics, are all specific to the standards as established by our collaborator. Our tool enforces these particular set of standards based on the data design and methods of a particular coach and ultimately provide a standard for our tool. First it is important to describe the relationship between the rows (which are player attributes) and columns (which are the player elements) and the corresponding value for each table cell. The cells have been ordered with a distinct letter (A to Z) if the value is either a percentage or an aggregate value type. Any cell that is denoted with the letter 'L' implies that the cell value is a Likert scale value. The data structure was provided as a table where each category is associated with the

following player elements: kick, head ball, throw-in, trap, tackling, dribbling, footwork, and ball protection. Execution mechanics for a player is comprised of precision, fluency, coordination, easiness, and rapidity. The precision attribute for all player elements are denoted by a percentage value; percentage of kick accuracy, head ball directed accuracy, throw-in accuracy to teammate, success of trap absorption, tackle success, ball position 50cm from foot while dribbling, success of feign for footwork, and success of ball protection. Fluency, coordination, easiness, and rapidity are all Likert values utilizing a scale of: unsatisfactory, satisfactory, good, and very good. This is denoted by the letter 'L' within each corresponding cell on the table. For example, the rapidity value of kick accuracy would be "L 4" which means a Likert value of 4 representing "very good". Again it should be noted that although it may be possible for other soccer coaches to use a five, seven, or n-point Likert scaling system, the 4-point Likert scale that is introduced in this chapter has been adopted from standards as specific to our collaborator. Tactical utility of a distinct player is specific to all elements and each are denoted by the number of times aggregate. The value for each element denotes the following aggregate totals:

- number of times surprising the opposing team
- head ball is used to remove ball from danger
- throw-in ensures continuity of offensive attack
- trapped toward the opposing goal
- tackles in defending half
- distance traveled in possession of ball while dribbling
- ability to create a man advantage
- number of times created advantage for opponent due to poor ball protection

For the frequency of mistakes in execution, the category comprises the player data for foot, torso, and the slow execution of movement attributes. All attributes are denoted by the Likert values as described above, however both the foot and torso denote a more fined grained characteristic as they are related to player elements. Foot attribute is broken down into the following element representations:

- plant foot during kick is too far from ball
- pauses to jump off both legs while running during a kickball
- does not keep both feet planted on throw-in
- plant leg is not flexible during trap
- hit opponent prior to hitting the ball during tackling
- repeated use of large steps on dribbling
- shifts center of gravity from one leg to another too slowly on footwork
- ball is not kept on opposite side of opponent's tackle attempt during ball protection.

The torso attribute of a player represents the following element values:

- leaning backwards during kick and trap
- moved back and forth too slowly during head ball and throw-in
- does not unbalance opponent when tackling
- is stiff and not leaning forward during dribbling
- center of gravity too high during footwork
- not able to keep balance when physical contact made by opponent during the act of ball protection

Conceptually, our application was designed to encompass all three categories with their respective element values all within a single viewing instance. This was visualized implementing a soccer field metaphor which utilized a variety of unique field objects; goal and net, center field marker, ball locations, opposing team player icons, and other visual metaphors. A glyph system [11] was implemented to represent any obscure data points which could be represented naturally by field objects such as the foot and torso attributes of the mistakes in execution frequency values.

Technically, the application was developed and implemented utilizing the Java language framework. For the graphics engine, the JOGL (Java Binding for the OpenGL API) Framework [12] was leveraged for generating the visualizations for data representations. The development environment includes the use of the Netbeans IDE (Integrated Development Environment) [13]. Version control was supported by Google Code [14] base made available through the web.

2.1 Field Viewer

Figure 2.1 The Field Viewer allows a team manager to view various attributes of a desired player dynamically.

The Field Viewer visualization allows a team manager of a soccer team to isolate a given player on a given team (see Figure 2.1). This visualization can be toggled to show different categories. The categories are kick, head ball, throw-in, trap, tackle, dribbling, footwork, and ball protection.

The overall visualization contains smaller visualizations to relay information [15] about execution mechanics, tactical utility, frequent mistakes in execution, and slow execution of movement of a respective category.

Before explaining each visualization in detail, it is important to recognize that the entire visualization is placed on a soccer field. The key aspect to this visualization is

familiarity [16]. The user needs to feel at home and must recognize the abstractions used to display the information. If the display is foreign, information might be misinterpreted.

2.1.1 Precision

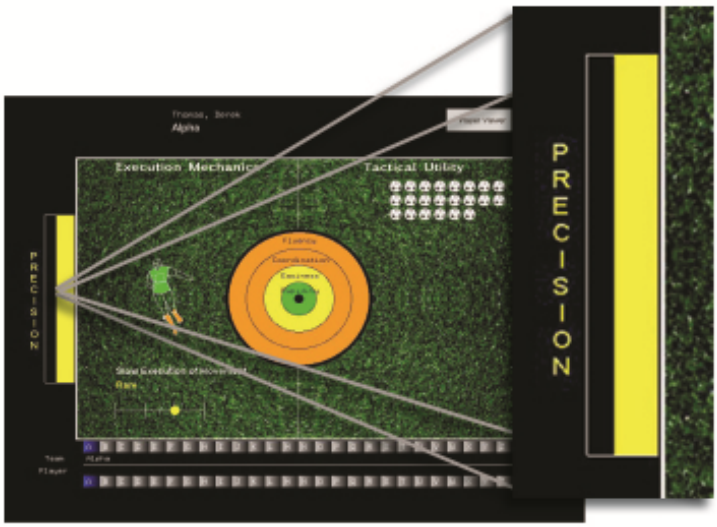

Figure 2.2 The soccer goal in the Field Viewer represents the precision of a player.

The soccer goal represents the precision of the player for a respective category (see Figure 2.2). It is appropriate that this attribute is represented with a soccer goal, as most people would associate precision with kicking a soccer ball into a goal when discussing soccer. The goal is filled up horizontally based on the precision value for the given category. The higher the value, the more filled in the goal is. The filled in portion of the goal will change color depending on the precision value. When dealing with human precognition, color is one of the first qualities of a visualization that stands out [17]. The goal is filled in red if precision percentage value is 0-25%, orange if it is 25-50%, yellow if it 50-75%, and green if it is 75-100%. If data is not available then no color is used. In our design it was important that we fill the goal in from right to left, as it was considered a more natural, realistic approach in establishing an association for soccer

team managers who may eventually use our tool that the right side of the goal in our visualization is at ground level.

2.1.2 Execution Mechanics

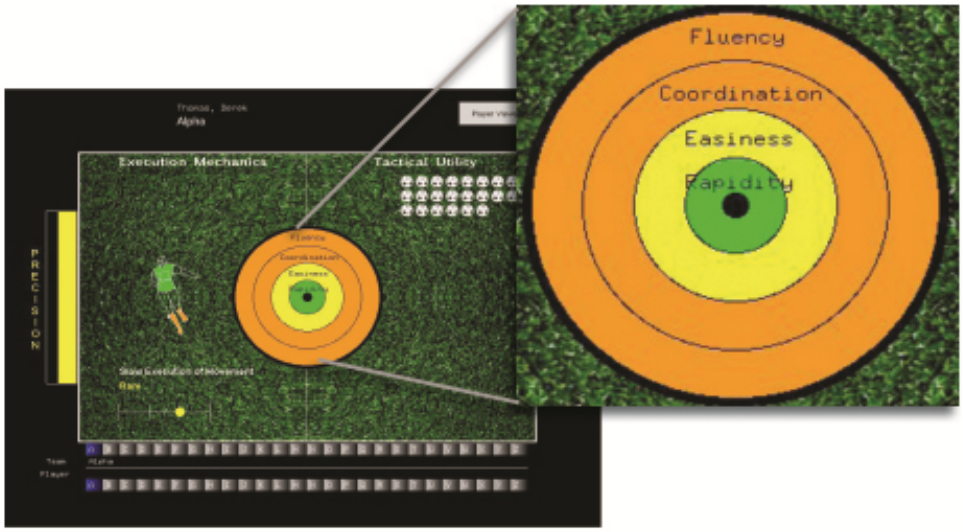

Figure 2.3 The center circle in the Field Viewer represents the execution mechanics of a player such as fluency, coordination, easiness, and rapidity.

The center circle in the middle of the field represents the remaining attributes that make up execution mechanics, which are fluency, coordination, easiness, and rapidity (see Figure 2.3). Initially, a star plot [18] was going to be used, but we decided that intersecting lines would have been confusing to the user. A similar coloring technique described earlier was applied to the rings of the center circle with each ring representing a different attribute. The rings, from inside to out, represent rapidity, easiness, coordination, and fluency. These attributes follow a Likert scale. If a player is marked as unsatisfactory, that particular ring is red. Satisfactory means the ring will be colored orange, good means the ring will be colored yellow and very good means the ring will be colored green. Once again, color played an important role in this visualization, as a team

manager will be able to clearly see which aspects of execution mechanics a player is deficient in.

2.1.3 Frequent Mistakes in Execution

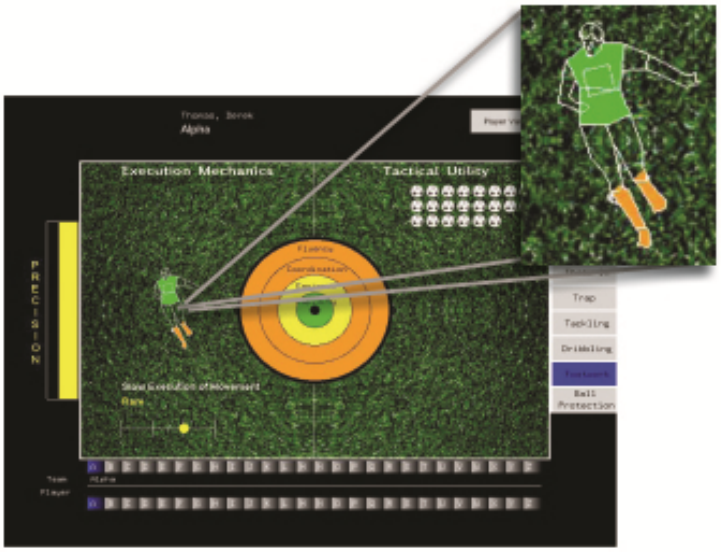

Figure 2.4 The wire-frame soccer player model in the Field Viewer represents the frequent mistakes in execution for both feet and torso.

To the left of the center of the field, there is a wire-frame model of a soccer player (see Figure 2.4). On this player, two regions are colored in, which are the torso and the feet. These colored regions represent the frequent mistakes in execution for the feet and torso. These attributes follow a Likert scale as well, as they determine how many times a player fails with either their feet or torso for a respective category. The same coloring scheme that was utilized for previous visualization is used again here.

2.1.4 Slow Execution of Movement

Figure 2.5 The four tick mark line graph in the Field Viewer represents the slow execution of movement attribute for a player.

The line graph with four tick marks represents the slow execution of movement attribute (see Figure 2.5). From the right to left, each tick mark represents the value of very rare, rare, often, and very often respectively. The meaning of "rare" implies that a player rarely makes an error and is always quick with response and execution of a technique, where as "often" implies that there is large margin of error and that the execution of a technique is rather slow. A colored circle will be placed on a tick mark depending on the Likert value for a given category. Further to the right means the player is fast in execution, whereas being to the far left means the player is very slow in execution. Coloring techniques [19] mentioned previously are used here again on the circle. Coloring was added to emphasize the Likert value. If coloring was not included, labels would have been implemented beneath each tick mark to indicate to the user exactly what the value is.

2.1.5 Tactical Utility

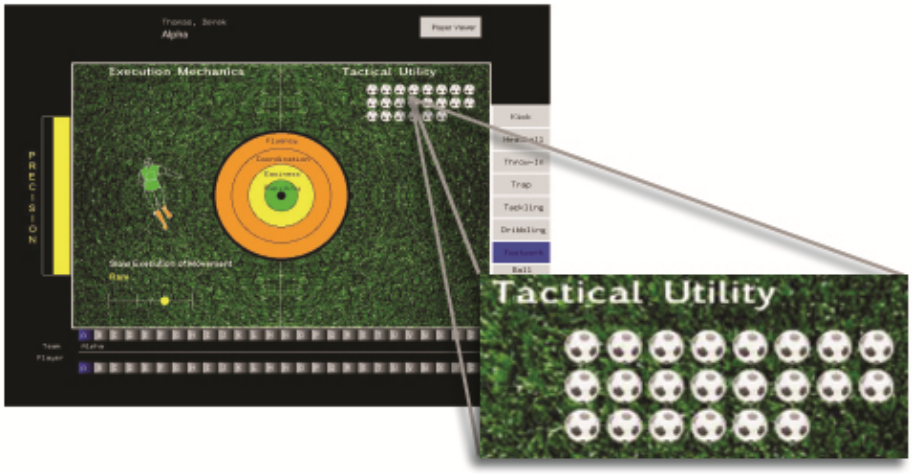

Figure 2.6 The number of soccer balls on the right side of the Field Viewer represents the overall tactical utility of a player.

Tactical utility is represented on the right side of the field with soccer balls (see Figure 2.6). Tactical utility is a sum, which means the more soccer balls placed on the field, the better it is for the opponent. Choosing a soccer ball as the glyph was important [20] for a couple reasons. Firstly, using a player would have been confusing, as a player already exists on the field. Secondly, a user associates success with scoring. The user seeing a lot of balls on the right side of the field leads to the user believing that this player is outstanding despite not even fully understanding the information being visualized.

The Field Viewer is a dynamic visualization that allows the user the ability to toggle quickly between different categories or even different players. This will allow a team manager to quickly pinpoint deficiencies in his or her starting lineup or determine what the best pairings are for the team.

2.2 Player Viewer

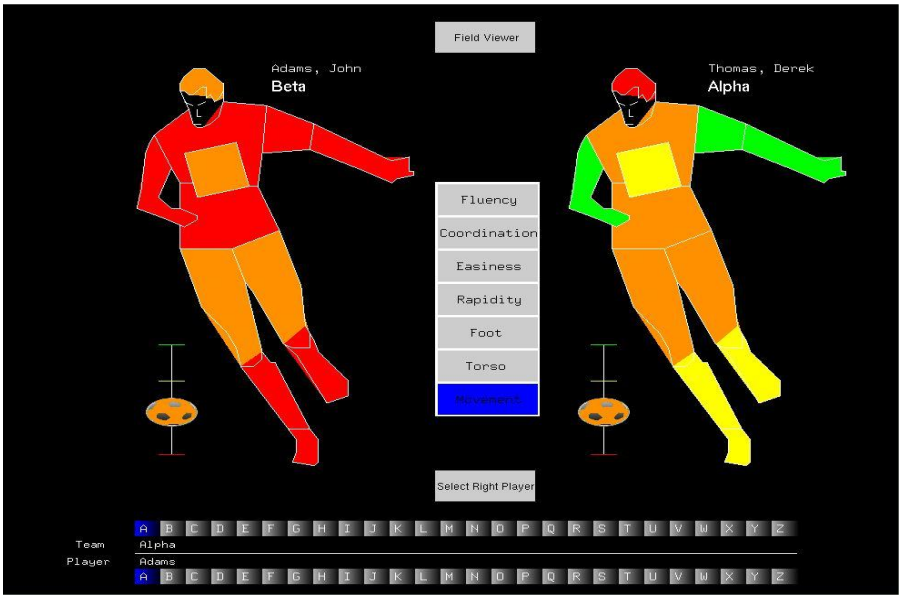

Figure 2.7 The Player Viewer allows a team manager to compare two players dynamically and determine who is the stronger player based on various categories.

The Player Viewer visualization allows a team manager of a soccer team to compare two players simultaneously (see Figure 2.7). This portion of the application contains two instances of the same visualization. The visualization is a wireframe of soccer player with a soccer ball. Each region of the player is partitioned and color coded to represent a different category. The head represents head ball, the upper legs represent kick, the arms represent throw-in, the feet represent footwork, the torso represents tackling, and the square in the torso represents trap. The color of ball represents the ability of the player to protect the ball (ball protection) and the height of the ball represents dribbling. Unlike the Field Viewer the categories that can be toggled are fluency, coordination, easiness, rapidity, foot, torso, and movement. The Field Viewer visualizes one complete row, that is a distinct player performance attribute (fluency, coordination, etc.) with all associated player elements (kick, head ball, etc.) of soccer data. Reciprocally the Player Viewer

visualizes one column, that is a distinct player element (kick, head ball, etc.) and all corresponding attributes (fluency, coordination, etc.) of soccer data.

The same coloring techniques are used for this visualization. The Likert scale is assigned appropriate colors to each value as well as each range from 0-100 for concrete values. For the height of the ball, a similar technique was used for the visualization to represent slow execution of movement in the Field Viewer. Each tick mark is color coded so the team manager understands the meaning of the height of the ball. We felt that labels next to each tick mark would have cluttered the visualization, so color was used instead.

The user is able to toggle their focus between the two player instances in this visualization; either player 1 to the left or player 2 on the right. The user is then able to choose a different player from the selection menu at the bottom. Dynamically, the player will be updated to reflect the new player chosen. The various attributes can be quickly selected by toggling when then reveals the performance details the player. Making this visualization dynamic and utilizing details on demand [7] will allow a team manager to quickly compare players. When developing this visualization, a key component was making it intuitive. When the user sees that the soccer player's head is red, the user should be able to deduce that they need practice at head balls. Although our design warrants actual user testing and evaluation in the future, we have attempted to make the right correlations between the player's anatomy and the data so that we can make this visualization as effective as possible.

2.3 Results Overview

The analysis of field data is critical to understanding the usefulness and uniqueness of the Soccer Scoop (Player Viewer and Field Viewer) visualization. This section explores the functionality of Soccer Scoop by outlining three specific case studies. These cases were developed and observed with the use of captured field data. Specifically, ten players of U Craiova soccer team from the Romanian soccer championship were observed over a period of five games (home advantage or away). Each player was closely analyzed during each game and data was hand-recorded according to a predetermined matrix of values (as listed in Table 1). The matrix was composed of the specific fields that have been described earlier in this chapter (player attributes with associated player elements) that provided a well-rounded and very detailed synopsis of a single player in a single game. Fields such as execution mechanics, tactical utility and frequency of mistakes were included in the matrix. Values for each category were distributed amongst different functional areas of play including kicking, tackling, dribbling, ball protection and other categories as mentioned earlier.

2.3.1 Single player analysis of the University of Craiova data using the Field Viewer

The Field Viewer highlights an individual player's skills and abilities. This unique visualization quickly provides all data for a single player on the screen at the same time. Through the use of familiar soccer objects (i.e. Player outline, soccer ball, field, goal, etc), the data is displayed in an aesthetically pleasing manner [21]. A quick observation of the visualization can effectively point an evaluator to specific player data while still providing an overall reference point for all of the player’s information. The Field Viewer

provides the ability to toggle the display between each of the categories found in the data matrix (kick, footwork, dribbling, etc).

2.3.2 Observation of an above average player

In this analysis, as seen in Figure 2.8, a player was observed to have highly rated skills. Particularly, in the Trap category, the player's information was easily displayed for quick evaluation. At first glance, a user can see that, although the player has a limited score of Tactical Utility and makes frequent mistakes with his feet and torso, the other skills of this player stand out to the user as mostly positive. According to the visualization, this player possesses more strengths than weaknesses, thus being considered an above average player. Precision, coordination, easiness, and rapidity are coded as green for this player representing the quality that this player brings to the team.

Figure 2.8 The Field Viewer for a University of Craiova player ranking above average in the Trap category

2.3.3 Observation of below average player

The captured data displayed in Figure 2.9 represents a player with significantly below average playing ability in the category of Throw-In. A quick observation of this visualization can easily show the user that this player lacks many of the favored skills to better the team. Precision, coordination, easiness and rapidity are all coded in the visualization as red, representing a poor mark during evaluation. It is evident that steps need to be taken to encourage this player to gain more experience and to focus on developing strengths in all categories.

Figure 2.9 The Field Viewer for a University of Craiova player ranking below average in the Throw-In category.

2.3.4 Comparison of two players from the University of Craiova data

The ability to compare players during a game or during practice sessions can be a challenge. Team managers from various sports can observe individual performances and take notes, but the focus tends to be on a single player and does not allow a team manager to quickly identify the differences between players. For the best player-to-player comparisons, the Player Viewer will be observed for this case. Once the player viewer is launched and the two players are selected the user is presented with a color coded comparison of the players. This color coding of the players makes their abilities immediately apparent to the user. The user can chose between different categories (fluency, easiness, rapidity, etc). When a category is selected the visualization will be redrawn to display the data from the corresponding column in the data matrix.

2.3.4.1 Easiness

As an example, looking at Figure 2.10 the user has selected the easiness category. When the visualization is drawn it can be easily inferred that the player on the left performs throw-ins with greater ease than the player on the right. As mentioned above, the soccer ball encodes two pieces of information: ball protection and dribbling. This visualization reveals to the user that although the player on the left performs dribbling with more ease than the player on the right, the player on the right can more easily protect the ball.

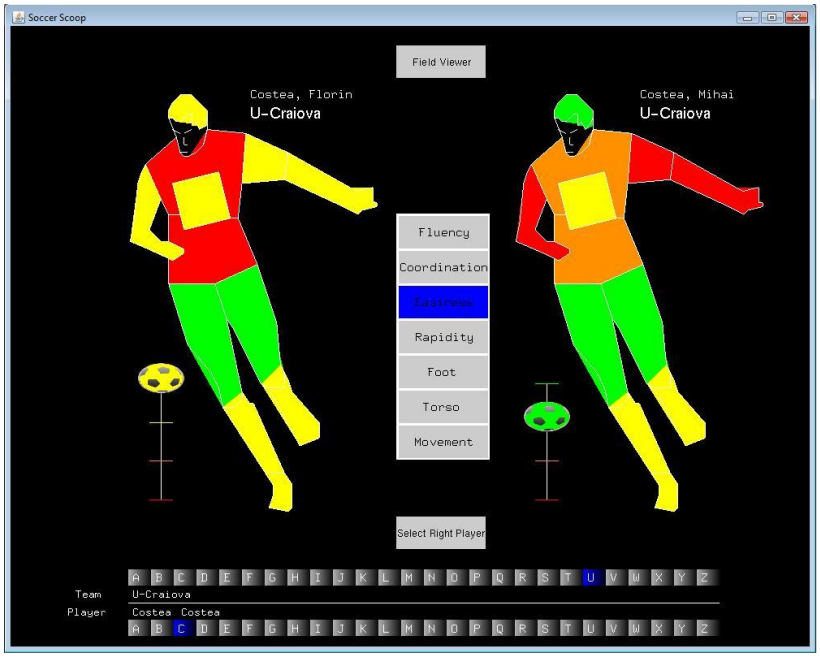

Figure 2.10 The Player Viewer after University of Craiova data has been entered for two different players. The Easiness category has been selected.

2.3.4.2 Fluency

In Figure 2.11 the visualization displays information for two players in the fluency category. It can be observed that the player on the left has an advantage of better fluency in his kicking. Despite this advantage, this player lacks fluency in footwork and tackling as compared to the player on the right. However, a quick overall observation quickly reveals that both players perform similarly on the field in several categories. This information could prove to assist the coach in placing these players in similar position on the field during a game.

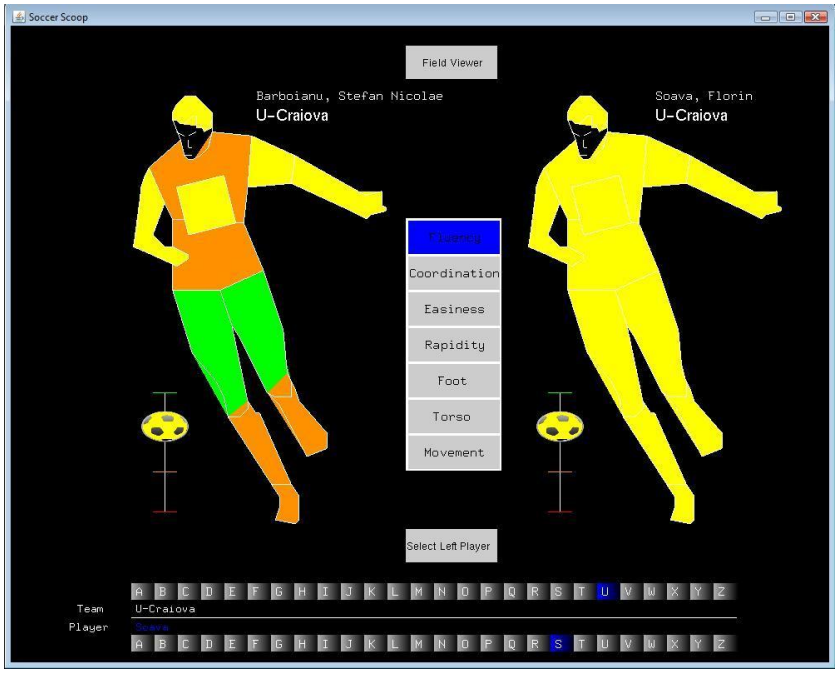

Figure 2.11 The Player Viewer with the Fluency category selected.

2.3.5 Comparison of the entire team analysis (average) between home and away games

Team managers might be limited to only evaluating a player in the setting/location at hand since the player cannot be in two places (home and away) at the same time. This complication forces the team manager to rely on visual or statistical memory of the player's performance in a different setting. Even with the separate captured data from home field and an away field, accurate estimates of a team's performance may be unclear due to the fact that comparing matrices side-by-side is not easy to evaluate at a glance [22]. Soccer Scoop provides a better way to give team managers insight into how their team performs at home and on the road. Since sport teams have demanding schedules during a single season, the overall team performance at various locations deserves careful evaluation. Critical data captured over a period of games performed at a team's home field and during away games could determine key

strengths and/or weaknesses of a team. This particular case attempts to show a glimpse into what Soccer Scoop can be used for in determining the performance of the team as a whole during home games and away games. Captured field data was consolidated into two categories. The first category grouped all player data for home games. The second brought together all data for away games. With these two categories, all player data was averaged together for all home games and all away games. In essence, this case sought to display the entire team average for home games in a single player visualization. Similarly, a single player visualization was used to represent the overall team average for away games. This separation of home and away game data allowed Soccer Scoop to treat the data sets each as a single player, thus being able to display these player visualizations side by side for evaluation. The visualization generated from this data can be seen in Figure 2.12. At first glance, this particular comparison of the University of Craiova data shows that the team generally performs similarly in rapidity regardless of playing at a home or away game. However, careful evaluation further reveals that the rapidity of the team's trapping and dribbling is better in away games. It can also be seen that the team is better at protecting the ball at home. These discoveries can assist the coach in developing exercises and practice sessions to better the team overall in areas that need improvement.

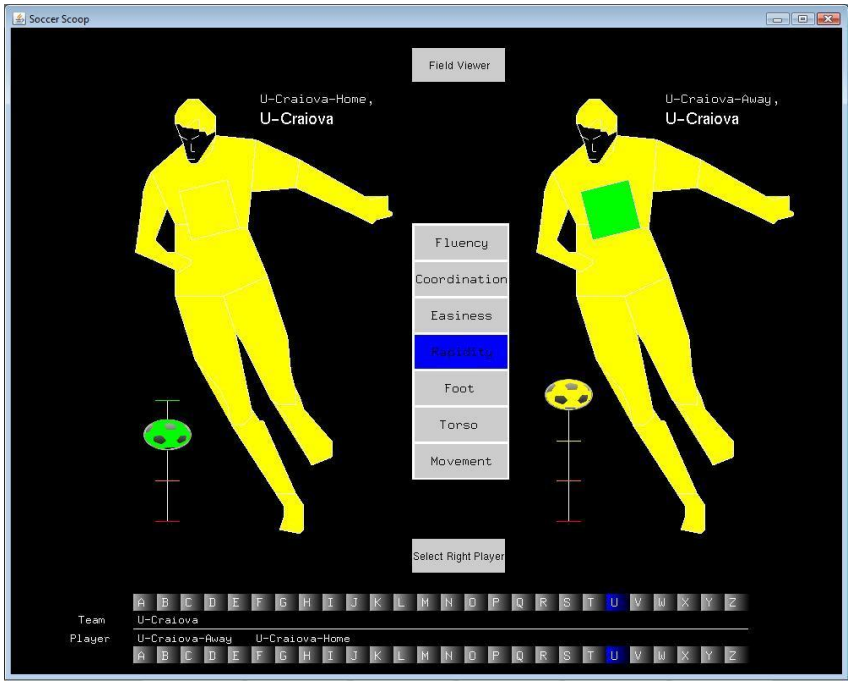

Figure 2.12 This figure represents a comparison between a team's average performance at home versus average performance at away games. All player data was averaged together for all home games (left) and all away games (right).

2.4 Results Summary

The case studies described above represent a small subset of possibilities that Soccer Scoop can be used to evaluate. The focus of the cases was on the performance of a single player using the Field Viewer, the comparison of different players using the Player Viewer, and the evaluation of the data averaged from the entire team performance during home games versus away games. The intent of the Soccer Scoop tool is to empower coaches with the ability to analyze and evaluate the team efficiently and effectively. With an intuitive representation of the player's skills highlighted by a basic color scheme, decisions can be made and practice exercises can be determined for the team and individual players. Soccer Scoop quickly displays not only the best skills of each player, but also highlights any skill deficiencies that may be in need of improvement. This

provides an overall picture of the level of performance of a specific player and can be beneficial for player development during coaching. Allowing coaches to focus on the goal of improving or harnessing the skills of specific players, may indirectly and ultimately improve the overall performance of the team.

2.5 Conclusion

In this chapter we presented Soccer Scoop, a visualization application that is comprised of two main soccer player visualizations. Both represent distinct player characteristics as related to specific player dynamics. However, it is also possible to use the same visualizations to establish an analysis based on aggregated data of multiple players on a single team (for example home versus away stats) or between two teams (for example team 1 versus team 2 for overall stats), thus fulfilling the need for coaching analysis related to player specific or team specific skill-set data. Our quick-glance observation technique is made possible by leveraging a soccer field metaphor that encapsulates a complete set of skill-set categories with associated attributes and cross references each element of a player represented by natural objects located on the field. Ultimately, through quick observation and analysis as implemented by our application, coaching will benefit by achieving the ability to categorize players, focus in on a skill quality or deficiency, and perhaps establish better strategies in terms of overall team development and success.

Chapter 3

Visualization for Goalie Player

In this chapter we first define specific attributes (data model) that characterize goalkeeper performance, and then present a solution[4] for goalkeeper analysis, both for individual comparisons between games and player-to-player between games. The overall goalkeeper dynamics of a specific player are represented and modeled using specific structure of data elements provided for the requested goalkeeper visualization. The data model contains three main data attribute categories with associated elements, with the target of allowing for the observation of both offensive and defensive goalkeeping, establishing a determination of performance level, and exposing specific performance characteristics that would otherwise remain hidden without a proper method of presentation.

We define the data model for goalkeeper to be similar to that of the original data model as provided for the original player visualizations, as presented in chapter 2 (see Table 2). The main categories are: execution mechanics, tactical utility, and common mistakes in execution. What differs is that each of the categories are associated to element characteristics specific to goalkeepers: ball catching, lunge, boxing ball, diverting ball, hand throwing, blocking, dribbling, and ball kick. Execution mechanics for goalkeeper is comprised of precision, fluency, coordination, easiness, and rapidity.

The precision attribute for the associated elements of a goalkeeper are denoted by a corresponding percentage value, corresponding to each of the characteristics specific for

[4] This chapter is primarily derived from a publication at the 15th International Conference on Information Visualization (IV 2011) in collaboration with Adrian Rusu and Doru Stoica [23].

goalkeepers: percentage of success related to ball catching (from long, medium, or short range shots), catching the ball during a lunge, boxing the ball to the side, diverting the ball to avoid goals, hand throwing to teammates, removing the possession of the ball from the opponent or removal of danger during blocking, percentage of time when the ball is 50 inches from the leg, and the percentage of success of ball kicking to teammates.

Table 2. *This matrix is used to collect data of a single goalkeeper during a game. The data can then be entered into a database and read into the application.*

			BALL CATCHING			LUNGE	BOXING BALL	DIVERTING BALL	HAND THROWING	EXIT FROM GOAL [BLOCKING]	DRIBBLING	BALL KICK
			total	unsuccessful	%							
EXECUTION MECHANICS	Precision	L				B	C	D	E	F	G	H
		M										
		S										
	Fluency		L			L	L	L	L	L	L	L
	Coordination		L			L	L	L	L	L	L	L
	Easiness		L			L	L	L	L	L	L	L
	Rapidity (Speed)		L			L	L	L	L	L	L	L
TACTICAL UTILITY			I			J	K	M	N	O	P	R
COMMON MISTAKES IN EXECUTION	Foot or Hand		S(L)			T(L)	U(L)	V(L)	X(L)	Y(L)	Z(L)	W(L)
	Trunk		a(L)			b(L)	c(L)	d(L)	e(L)	f(L)	g(L)	h(L)
	Slow Execution of Movement		L			L	L	L	L	L	L	L

Fluency, coordination, ease, and rapidity are all Likert values represented by a scale of: unsatisfactory, satisfactory, good, and very good. This is denoted by the letter ‘L’ within each corresponding cell on the table. For example, the rapidity value of diverting the ball would be “L 4” which means a Likert value of 4 representing “very good”. Again, as we have previously described in chapter 2, it should be noted that although other coaches may use a five, seven, or n-point Likert scaling system, the 4-point Likert

scale introduced within this chapter was derived from the data structure provided by our collaborator and we use this as a basis to establishing a standard for our tool.

Tactical utility of an individual goalkeeper is distinct for each data element as described above and denoted by the following aggregation value totals respectively: number of times the goalkeeper manages to take possession of the ball, lunged and the ball stayed with his own team, managed to extricate game space (players unwind and go after the ball), diverted the ball's trajectory outside of the goal area, safely sent the ball to a teammate who managed to receive the ball and keep it under his control, went out of the goal to block the striker and decreased his shooting angle, controlled the ball with his foot in order to waste time, and kicked the ball beyond midfield.

The common mistakes in execution category are comprised of specific goalkeeper data for foot or hand, trunk, and slow execution of movement attributes. These attributes are all represented using a similar, corresponding Likert scale; however, foot or hand, and trunk values are more specific to the physical performance characteristics of an individual player. The Foot or Hand attribute is broken down into the following representative elements:

- wrong position with arms and elbows apart, as well as ball catch which does not cover the back of the ball enough and does not provide it's amortization (corresponding to ball catching)

- while in lunge momentum does not resort to added steps, or arms are spread apart during flight, or landing is made with hands outstretched (corresponding to lunge)
- the jump from the ground is performed with whole foot or arm is not sufficiently extended from the elbow joint when the ball is hit (corresponding to boxing ball)
- the ball is amortized with the palm of the hand (corresponding to diverting ball)
- the ball is released late from the hand, making a curved path or for long distance throws, the center of gravity is not transferred from the back foot onto the front foot (corresponding to hand throwing)
- throwing feet first or does not choose the right time of the attack (corresponding to blocking)
- ankle is tense when the ball is touched (corresponding to dribbling), and impetus is too short (corresponding to ball kick).

The trunk attribute of the goalkeeper data represents the following element values, respectively, corresponding to each of the characteristics listed above:

- trunk is not tight
- contact with the ground is not made on the side of the trunk and not in natural sequence of its segments
- during the flight trunk muscles are not tense to help hit the ball with more power

- there is no synchronization between the trunk and the arms which divert the ball depending on the ball's trajectory and velocity
- trunk does not execute a twisting motion after the ball leaves the hand
- blocking the ball is executed with the trunk - thus the risk of injury is high
- the trunk is not bent forward and is rigid
- the trunk is leaning backwards

As with the original concept as followed by our earlier soccer player visualizations, our goalkeeper visualization tool was designed to encapsulate and integrate all of the three categories with respective data elements into a single view. This was accomplished by implementing a goalkeeper metaphor which uses a variety of unique visual cues, objects, and color styles; goal posts, goalkeeper player, and various sections of the goalkeeper player body model [24]. A simple glyph-based system [20] was incorporated by leveraging the natural objects of the player model in order to represent common mistakes in execution such as foot or hand and trunk attributes.

3.1 Goalie Viewer Visualization

The goalkeeper visualization as presented in this chapter has been integrated within the Soccer Scoop visualization software that was presented in Chapter 2 (see Figure 3.1).

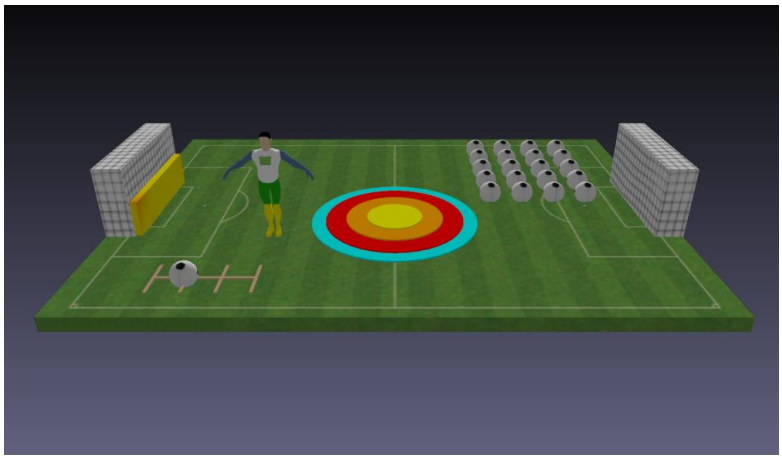

Figure 3.1 Goalie Viewer is integrated within the new version of the Soccer Scoop

The Goalie Viewer visualization, as shown in Figure 3.2, allows the manager of a soccer team to review an individual goalkeeper on a given team for a specific game. Additionally, it allows for the comparison of two goalkeepers of different teams for same or different games. Like our previous work, this visualization can be toggled to show different goalkeeper-specific characteristics: ball catching, lunge, boxing ball, diverting ball, hand throwing, blocking, dribbling, and ball kick. For example, in Figure 3.2, the lunge characteristic has been selected, and the same goalkeeper is projected in the same visualization twice to compare his performance in two different games.

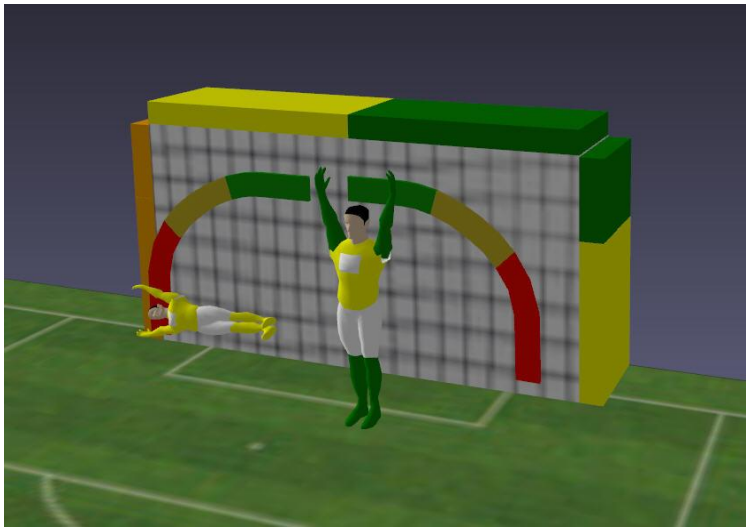

Figure 3.2 The lunge characteristic has been selected for a single player compared against two different games.

Overall, Goalie Viewer comprises of several visualizations with varying cues and visual styles that present information for execution mechanics (divided into its associated attributes of precision, fluency, coordination, easiness, and rapidity), tactical utility, and common mistakes in execution (divided into its associated attributes of foot or hand, trunk, and slow execution of movement) for the respective characteristic. It is important to recognize that the complete visualization is integrated into a soccer goal model. This is to keep with the continuity of our other player visualizations by providing the key aspect of familiarity [16]. In it is a necessary usability factor that the user must feel connected with the overall visualization and must be able to realize the various abstractions as related to goalkeeper data. If the presentation is foreign or not recognizable to the team manager or general user, the overall information may be misinterpreted or even not visible to the viewer.

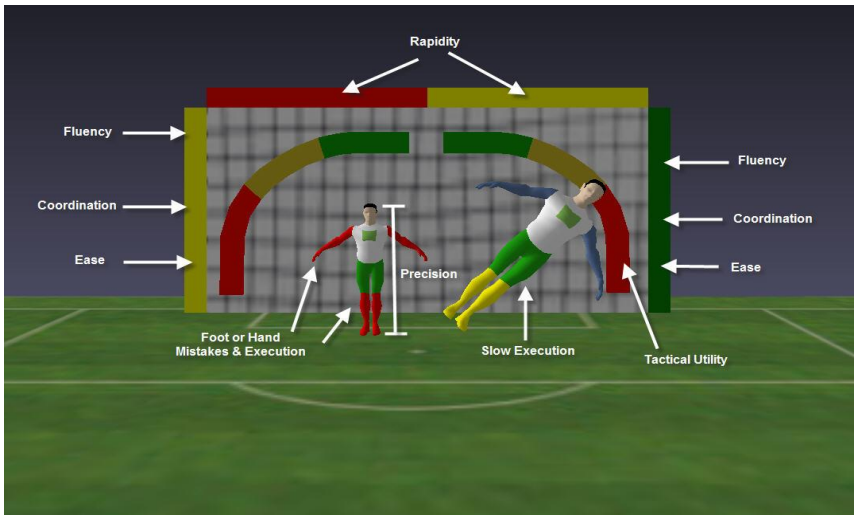

Figure 3.3 Goalie Viewer allows the manager of a soccer team to review or compare goalkeepers.

To implement comparative goalkeeper analysis, the visualization uses two instances of the same visualization (see Figure 3.3). The mesh goalkeeper model uses color coded [4] regions to represent the category of common mistakes in execution. By default, if data is not available, color white is used. Otherwise, the Likert scale corresponding to the attributes of this category are assigned in the same way as for the field viewer: green represents very good, yellow represents good, orange represents satisfactory, and red represents unsatisfactory. Hand and foot is considered one attribute, so goalkeeper's hands and feet will always have the same color. For example, in Figure 3.2, the goalkeeper on the right side performs very good on one or more of the following actions: resorts to added steps while in lunge momentum, arms are close to each other during flight, landing is made with arms bent (the value associated to lunge for hand or foot attribute). The trunk of the goalkeeper is associated with the trunk attribute. For example, in Figure 3.2, both goalkeepers have good evaluations for making contact with

the ground on the side of the trunk and in natural sequence of its segments (the value associated to lunge for trunk attribute). Slow execution of movement attribute is represented by the thighs of the goalkeeper. For example, in Figure 3.2, both the right and left goalkeepers have white thighs, which represents that data is not available for this attribute.

The category of tactical utility is represented in the visualization by the angle of a player model directly positioned from a gradient meter model that is color coded to red, yellow, and green to represent numerical ranges such as 0-5 for poor, 5-10 for good, and 10-20 for great, respectively. The player model works like a meter that will allow a team manger to visually recognize the performance of the goalkeeper during a specific game based on appropriate skill category. A straight goalkeeper is naturally associated with great work, so the player-meter metaphor would lead a team manager to understand goalkeeper's performance without much effort or knowledge of the data. For example, in Figure 3.2, the goalkeeper on the right side has been able to lunge and keep the ball with his team more than ten times (the value associated to lunge for tactical utility category).

Within the execution mechanics category, precision attribute is represented using the scale of the player model. Scale of the player model relative to size of the goal is associated to a percentage value for each skill attribute. The larger the player model the greater (and thus better) the precision; smaller models have poorer precision. This visualization technique allows for a team manger to quickly compare an individual goalkeeper or goalkeepers by associating precision with the idea that a taller goalkeeper relative to goal height will ultimately possess more precision performance overall. For

example, in Figure 3.2, the goalkeeper on the right side has more precision in catching the ball than the goalkeeper on the left side.

Within the execution mechanics category, the right goal posts (or left depending on the side) and the top goal posts within the visualization represent the attributes of fluency, coordination, easiness, and rapidity, respectively. The posts (right or left) are separated into three sections; fluency at top of post, coordination in middle, and easiness at base of the post. Each attribute is color coded to denote the appropriate Likert scale value. For example, in Figure 3.2, the goalkeeper on the right side has very good values for his rapidity and fluency, and good values for coordination and easiness of lunge.

When developing a visualization, the main goal is making it as intuitive as possible for the target user. By leveraging the natural elements of a goal such as posts, or the mesh goalkeeper model positioning, a team manager is able to deduce the many performance characteristics as associated with a particular goalkeeper. When the team manager observes that the goalkeeper model is small compared to another model for blocking, they should be able to deduce that they need to practice at blocking. Finding the connections between the data and the overall visualization by the use of metaphors makes our visualization an effective analysis tool.

3.2 Implementation Details

Recall from chapter 2 that the initial, original release of our Soccer Scoop (Field Viewer and Player Viewer) application was designed and written using the Java language framework and using JOGL, a Java implementation of the OpenGL graphics library, and implemented in the Netbeans IDE. Although this suited well for cross platform

deployment, we decided to take the Goalie Viewer tool into the realm of 3D while leveraging a more unified programming model that could incorporate UI, data, and media. As it was decided to include the Goalie Viewer as an additional tool within the Soccer Scoop suite, it was also necessary to rebuild Soccer Scoop around the same framework that we used for the Goalie Viewer. We chose Windows Presentation Foundation (WPF), implemented in the Visual Studio 2010 IDE, for the Soccer Scoop rebuild, as well as for implementing the Goalie Viewer as presented in this chapter. WPF is a development platform available within the .NET 3.0 Framework that provides a consistent programming model for building next generation software applications. It uses DirectX for graphics processing and provides a separation between both the user interface and the business logic layers which are generally written in the C# programming language. It was designed to unify some of the common elements of user interfaces such as documents, text, 2D and 3D rendering, vector graphics, and runtime animation. In WPF, the presentation or UI layer can be written in XAML, which is a derivative of XML, to define the many elements or models; however, it is also possible to define these models within the business logic layer with traditional graphics using the C# programming language. For the purposes of our design, we implemented the 3D models using XAML and implemented any transformations or animations using C# graphics programming. Version control was supported by Microsoft's Visual Studio Team System (VSTS) platform through Team Foundation Server.

3.3 Results

The application and analysis of actual goalkeeper data is critical in determining the usefulness of the Goalie Viewer visualization tool. In this section we explore the overall functionality of our goalkeeper visualization by presenting several case studies that leverage captured goalkeeper data. The data consists of a single goalkeeper of a second division University of Craiova team from Romanian soccer championship as an observation over a fifteen game period. These games were played both home advantage and away. Each data table comprises specific data attributes that provide for a detailed description of the goalkeeper within a single game, so a total of fifteen data tables have been collected. The data tables contain specific values for categories, attributes, and characteristics, as described in the beginning of this chapter.

3.3.1 Observing performance deficiency

In this analysis, as seen in Figure 3.4, a goalkeeper was observed to have a performance deficiency with diverting balls that remained consistent between games. This deficiency lies within the tactical utility category required for the technique. The angle of the goalkeeper shows that he has diverted less than five balls outside of the goal area in both games considered (left and right). Upon viewing the visualized data specific for diverting the ball from the goal, one can see that although the player may possess this deficiency within the tactical utility attribute, overall fluency, rapidity, coordination, easiness, as well as precision appear to be improving from the game depicted on the right side to the game depicted on the left side. These attributes are represented as the green and yellow colored left goal posts in contrast to the orange colored posts relative to the right

goalkeeper. Improvements in precision can be observed by comparing the size differences of the player models. Similarly, by comparing goalkeeper's performances over several matches, it has been observed that he is also deficient in his blocking characteristic spanning several categories (not shown in Figure 3.4).

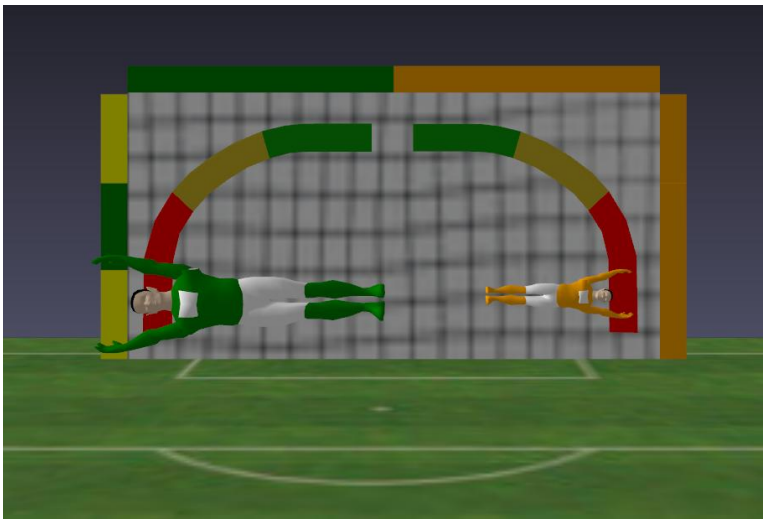

Figure 3.4 This figure represents a comparison of a goalkeeper between games in order to determine a performance deficiency.

3.3.2 Observing hidden performance qualities

It is equally as important to discover performance qualities as it is discovering deficiencies. In this case study, the performance attributes of an individual goalkeeper were compared between several games in order to detect exceptional qualities. Observation and analysis of the data through the goalkeeper visualization exposes ball kick as an exceptional performance characteristic (see Figure 3.5). It is evident through the visualization that the goalkeeper exceeds expectations for the two games selected, as shown by the mostly green and yellow coloring associated with the various elements of the metaphor. This is an important feature; by focusing in on performance qualities, the

manager of a team is able to discover hidden talents of a specific goalkeeper. Furthermore, this fine grained discovery may not only assist in the establishment of new training measures for existing goalkeepers within a team, but may also prove to work well for the recruiting of new and undiscovered talent.

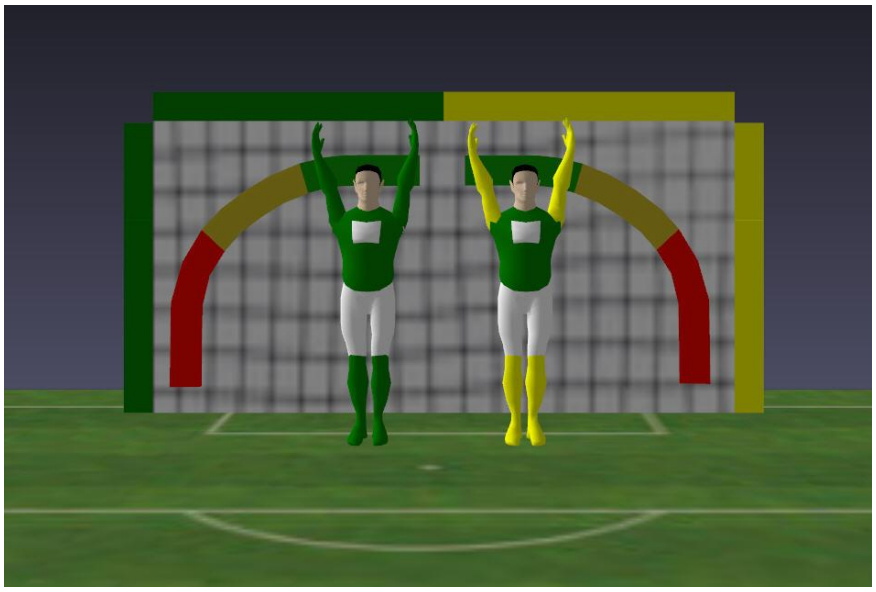

Figure 3.5 Goalie Viewer reveals the hidden performance qualities of a goalkeeper

3.3.3 Comparison of an individual goalkeeper characteristic between home and away games

Managers of soccer teams are sometimes limited to visual or statistical memory when attempting to compare and evaluate the performance of a goalkeeper between games home or away. Even considering the fact that a team manager may collect data between remote games, accurately interpreting this data may be still unclear as it is sometimes difficult to cross reference matrices [25]. Additionally, detecting performance improvements or deficiencies just by glancing at the numbers may not be easy. Our goalkeeper visualization solves this problem by providing the team manager insight into how their goalkeepers perform in games played at home relative to games played away.

In this case study, we show how Goalie Viewer can be leveraged to determine performance gains or declinations between home or away games.

Results for one home (left side) and one away (right side) game for the ball boxing characteristic are presented in Figure 3.6. At first glance, it can be observed that there is definitely an advantage between a goalkeeper playing at home versus away. It is evident that for some games there is a decline in the performance areas of tactical utility, precision, and rapidity as related to ball boxing. Additionally, the goalkeeper is much more prone to foot or hand mistakes. The only attributes that seem to remain consistent for the ball boxing characteristic are fluency, coordination, easiness, and trunk mistakes. Although specific to an individual goalkeeper, a performance may also be dependent on the performance of the overall team. Playing away may require the goalkeeper to contribute much more during the match, thus leading to more mistakes. As such, an evaluation of the general performance of a goalkeeper may in fact be indicative of team play. These discoveries can ultimately assist with the development of coaching exercise or other training practices that focus specifically on the performance deficiency that may be in need of improvement.

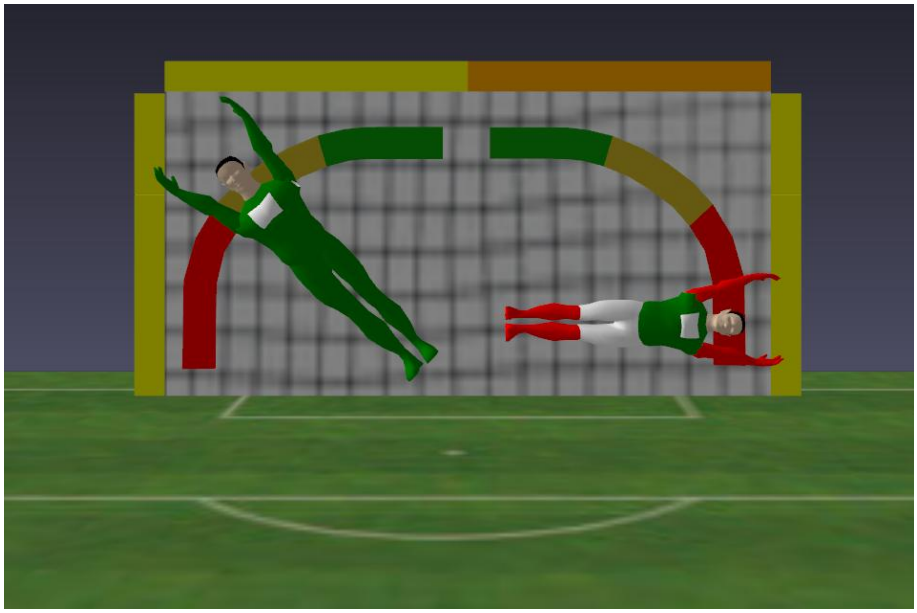

Figure 3.6 This figure represents a comparison between a goalkeepers performance at home (left) versus performance at away (right) games.

3.4 Results Summary

We presented three case studies that use various scenarios in order to find hidden information, such as performance deficiencies or qualities, as well as comparison between home and away matches, for selected characteristics. These scenarios represent a small subset of what the Goalie Viewer can be used for, in terms of evaluating the performance of a goalkeeper.

The main intent of the Goalie Viewer visualization tool is to empower team managers with the ability to evaluate, analyze, and observe the performance of an individual goalkeeper between games or with other goalkeepers of other teams between games so that decisions regarding the development of appropriate training or practice exercises can be devised. Our goalkeeper visualization tool quickly presents not only the best performance attributes of a goalkeeper, but also highlights any attribute deficiencies that are in need of further development. This is beneficial as it will allow coaches to focus in

on specific areas of strengths or weaknesses, thus ultimately improving overall goalkeeping performance.

3.5 Conclusion

In this chapter we presented the Goalie Viewer addition to our original Soccer Scoop visualization application that is centric around goalkeeping performance data. Our tool represents individual goalkeeper dynamics specific to a particular game, however like our previous efforts in the realm of player visualizations, the goalkeeper visualization allows for establishing an analysis of goalkeeper-to-goalkeeper between games, as well as between teams. This fulfills the need for team manager coaching analysis related to specific goalkeeper performance data. Leveraging our unique quick-glance observation technique, we are able to metaphorically encapsulate and represent a complete set of skill-set categories centric around goalkeeping with their associated attributes and cross referenced elements by establishing a goal model that uses natural objects to represent the data. With analysis through quick observation as implemented by our goalkeeper visualization, team managers benefit from the ability to evaluate the goalkeeping with focus on performance qualities or deficiencies, and thus empowering them to not only take control of their team, but perhaps allowing them control over the outcome of the game.

Chapter 4

Animation Principles for Player Performance Analysis

To enhance the effectiveness of our visualization tool we employed several animation principles to both the player viewer and goalie viewer visualizations. The use of animations has allowed us to further bridge the gap between the metaphoric representation of the data and the performance attributes which the data describes. Respective to the performance attributes characterized by each player, the animation principles that we appropriately incorporated were timing, squash and stretch, arcs, staging, anticipation, secondary action, follow through and overlapping action, and exaggeration. By heightening the overall metaphoric nature of our visualizations the team manager can benefit from the ability to quickly and seamlessly make an analysis of the data without the need for large degree of visual interpretation.

4.1 Timing

The animation principle of timing was incorporated into both the Player and Goalie viewer visualizations to represent the performance attribute of easiness. For the player visualization, the easiness comparison of two players is done by visualizing the speed of the two players. This was accomplished by shifting the original player viewer into an overhead view upon selecting the easiness attribute toggle, at which then the visualization presents two distinct players with a timing animation that spans from goal-to-goal and expresses the overall easiness of each player (see Figure 4.1). Players then can be compared by selecting from a single team or between two teams. An animated

timing of a player that is faster than the other implies that the overall easiness of that player is far superior in comparison.

The principle of timing animation within the Goalie viewer for the attribute of easiness can be visualized by the wobbling effect of the goalie player models. The comparison of the timing and speed of the wobbling animation of the players directly correlates to the overall easiness of a player and presents the ease of skill and overall quality of how quickly the goalie player will be able to ease into a ball-receiving or defending position. In comparing the attribute of ease between two goalie players the wobble timing between the goalie models denotes that faster is better.

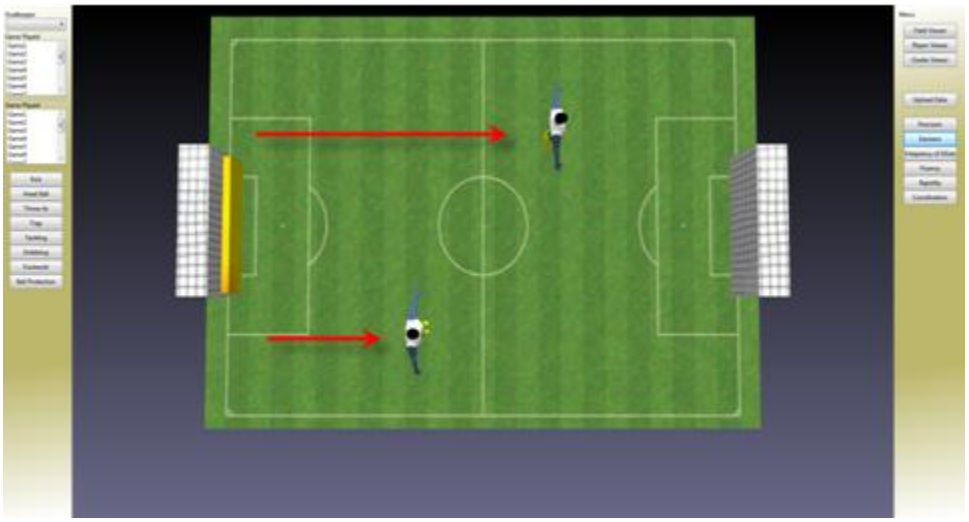

Figure 4.1 The animation principle of Timing is leveraged to represent the Easiness between the comparison of two players. The red arrows are used only for the purpose of demonstrating the path of the animated object.

4.2 Squash & Stretch

The squash and stretch animation principle represents the frequency of mistakes of execution for both players and goalie players within our visualization. This is

incorporated into the player visualization by the squashing and stretching of a ball model corresponding to each respective player (see Figure 4.2). Upon selection of the frequent mistakes in execution attribute toggle, the comparison of a player between distinct team or teams is possible and the comparison of frequency of mistakes in execution between each player can be visualized by the squash and stretch of the ball which implies the overall clumsy nature of the individual. The metaphor is achieved by the rate at which the ball corresponding to a player squashes or stretches. A ball that has a seemingly stable form, with little or no squashing or stretching, indicates that a player has a low rate of overall execution mistakes.

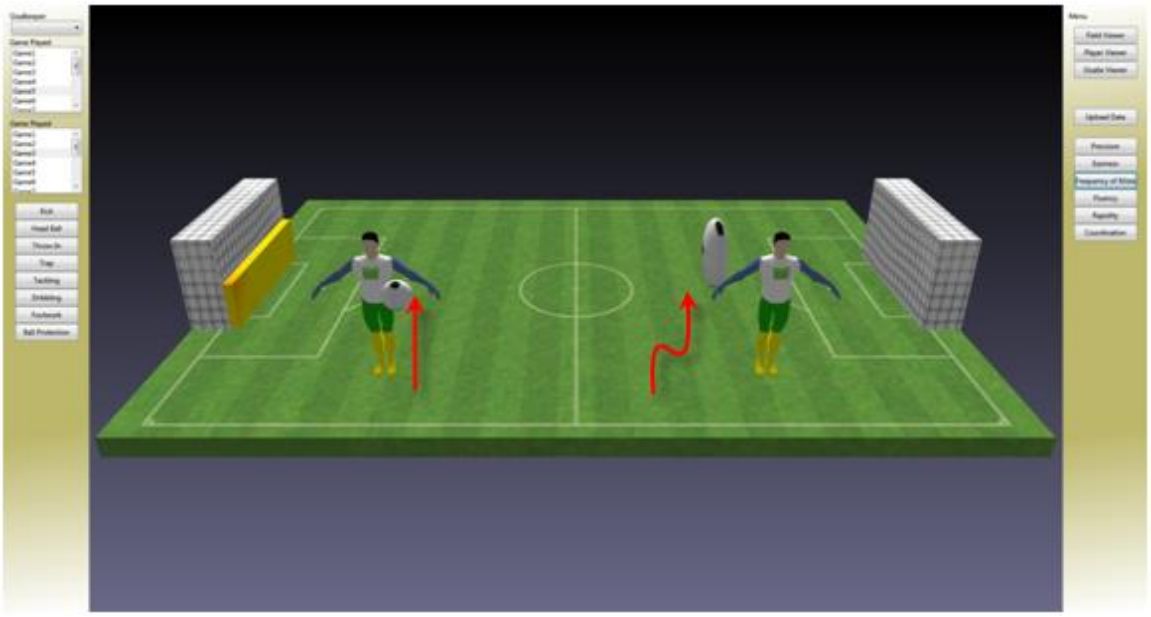

Figure 4.2 The animation principle of Squash & Stretch is applied to the ball model within the visualization to compare the Frequency of Mistakes between two different players. The red arrows are used only for the purpose of demonstrating the path or deformation of the object.

This principle of squash and stretch animation is applied to the goalie viewer similarly with the rate of ball deformation representing the frequency of execution mistakes of the goalie player, however this visualization is limited only to a single player analysis. Upon clicking on the mistakes of execution attribute, the goalie visualization pans to the side of the goal and highlights a single player, followed by a repeated animation of a receiving ball coming toward the goalie. The squash and stretch animation begins upon contact with the player models outstretched hands and the frequency of squash and stretch signifies the frequency of mistakes upon execution of skills such as catching or blocking.

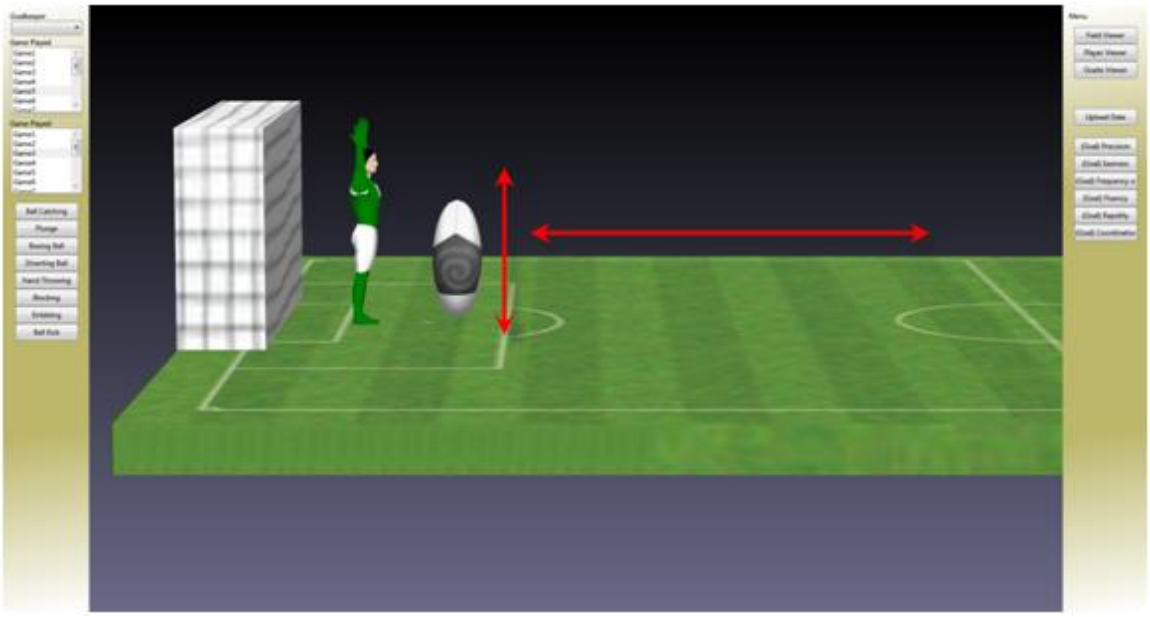

Figure 4.3 Squash and Stretch allows for the representation of Frequency of Mistakes by the deformation of a traveling ball as it approaches a goalie within the Goalie Viewer. The red arrows are used only for the purpose of demonstrating the path or deformation of the object.

4.3 Arcs

Leveraging the animation principle of arcs for both the player and goalie viewers, we were able to denote the fluency attribute of a player within our visualizations. For the player viewer this was accomplished by establishing an animation that was uniquely suited for such attribute. Upon toggling the fluency attribute, the field viewer rotates sideways at face view and reveals a player and a ball that repeatedly animates along an arc from player-to-goal. The arc of the animation is a metaphoric representation of the fluent nature of a particular skill such as the attributes of kick or head ball with the curve height of the arc representing the overall skill quality. A heavily arced animation is an indicator of a less fluent action respective to the skill of interest, however a more straight forward, less arced animation from player-to-goal indicates a greater fluency (see Figure 4.4).

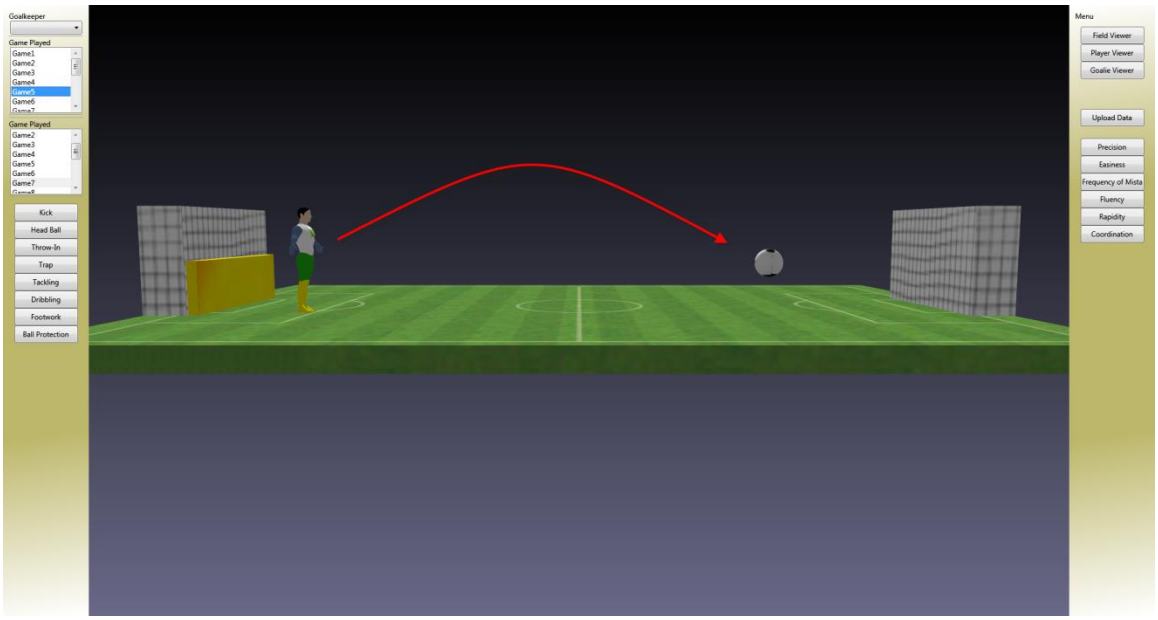

Figure 4.4 Arcs animation principle represents the fluency of the player. The red arrows are used only for the purpose of demonstrating the path of the animated object.

Similarly, the goalie viewer implements all the characteristics as we have described for the arcs animation principle implementation within our player viewer; with only a single player and side view orientation upon selection of the fluency attribute. Again the arc curve established from the ball leaving the player denotes the overall fluency of the goalie player. Like the player viewer, a large arc implies the weakest goalie fluency performance, where a less curved is one that denotes poor fluency performance (see Figure 4.5).

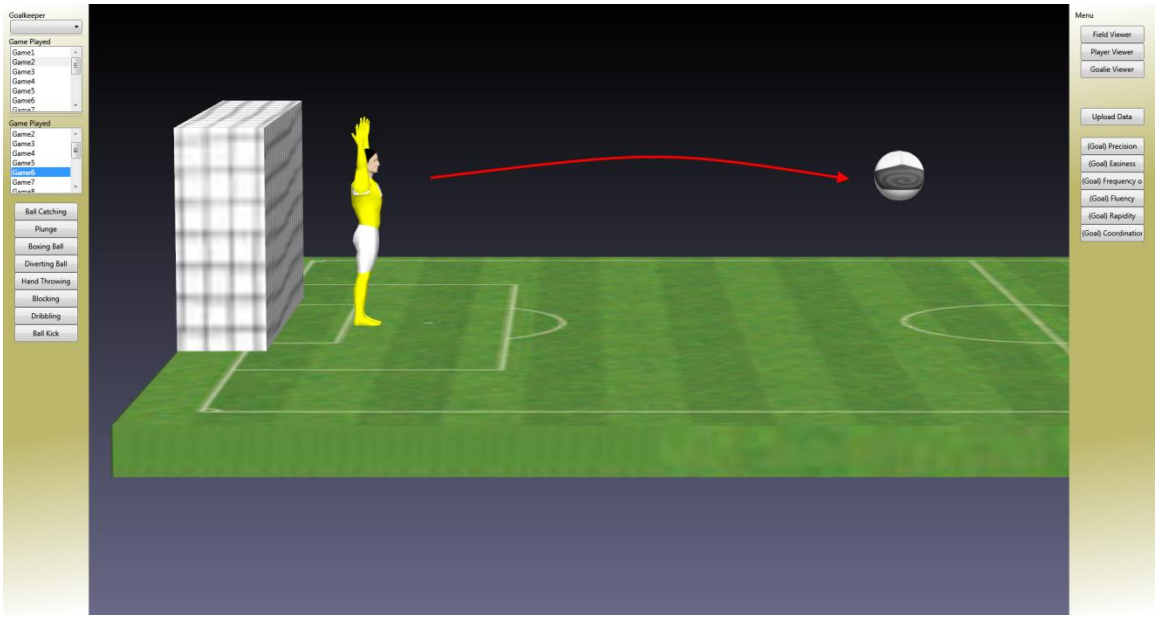

Figure 4.5 Fluency of a goalie player represented by the Arcs animation principle. The red arrows are used only for the purpose of demonstrating the path of the animated object.

4.4 Staging, Anticipation, and Secondary Action

Within our visualizations we have enhanced the metaphoric power of our visualizations by incorporating a composite set of animation principles including staging, anticipation, and secondary action to establish a higher level of visual analysis. This can

be seen within both our player viewer and goalie viewer visualizations. For the player viewer, the combination of the three principles described work in tandem to allow for performance analysis at a quick glance. Upon toggling the precision attribute the field viewer rotates to reveal a perspective view at which the player is staged in front of the goal and a ball coming in from the distance. The anticipation principle is established by the ball contact with the player and what the viewer anticipates will happen upon contact. It is upon ball contact that the secondary action principle is established as the player moves towards the approaching ball to perform a kick toward the goal. Performance analysis is based on the angle at which the ball relates to the original ball position and the goal after the ball has been kicked by the player (see Figure 4.6). A kick from the player to the goal that is straight and perpendicular to the player, represents excellent precision, but a kick that is an angle that is acute yields less precision.

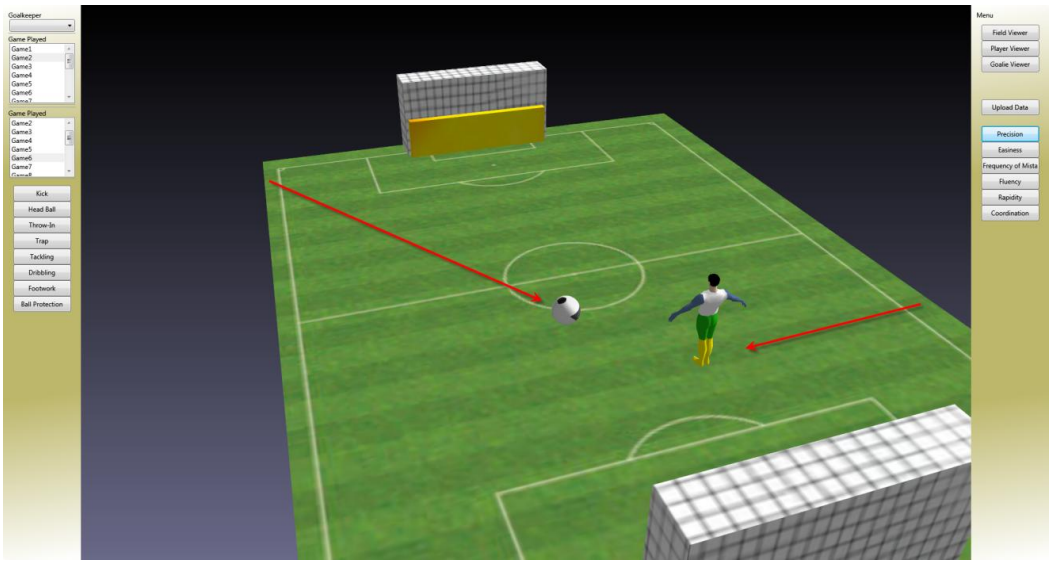

Figure 4.6 A composite set of animation principles consisting of Staging, Anticipation, and Second Action allow for the determination of a player's precision. The red arrows are used only for the purpose of demonstrating the path of the animated objects.

For denoting precision for the goalie viewer, and to keep with the continuity of our visualizations, we leveraged the composite of staging, anticipation, and secondary action animation principles in similar fashion. Upon toggling the precision attribute, the goalie viewer is staged in such a way that single player will be revealed and a ball will be seen coming in from the distance approaching the goalie player. Like the player viewer, anticipation is established by the approaching ball to the goalie player at which one would assume that a counter action upon the ball would be performed. Upon ball contact with the goalie player, the secondary action is established by the movement of the goalie player toward the ball which is symbolic of deflecting the ball. Precision analysis based on these composite set of animations is based on the angle at which the ball leaves the goalie player upon contact and deflection (see Figure 4.7). However unlike in the player viewer, an angle that is perpendicular to the goalie player as it leaves the goal is representative of bad precision, however one that forms an acute angle off of the player denotes excellent precision.

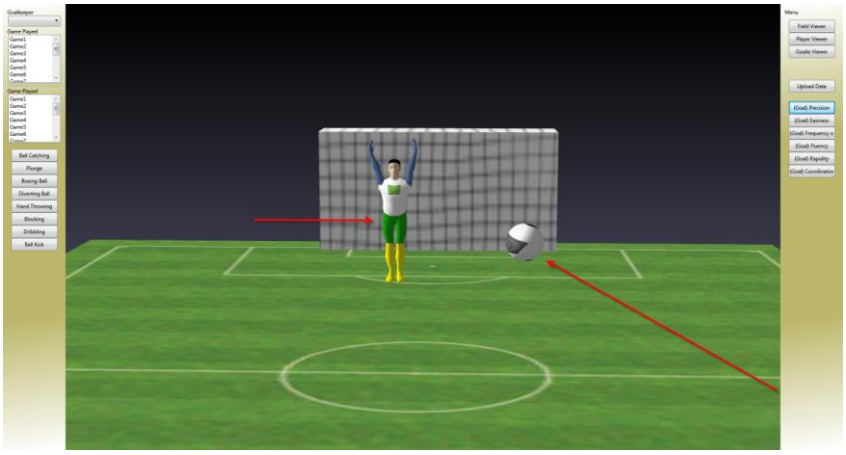

Figure 4.7 Staging, Anticipation, and Secondary action as applied to the Goalie Viewer for the representation of the precision attribute. The red arrows are used only for the purpose of demonstrating the path of the animated objects.

4.5 Follow Through and Overlapping Action

By incorporating the animation principle of follow through and overlapping action for both our player and goalie visualizations we were able to represent the performance attribute of rapidity. This is accomplished by toggling the rapidity attribute within the player viewer which rotates the field viewer to a frontal view perspective and then reveals a single player and two goals. The analysis of the rapidity of the particular player is established by visualizing the speed of the sprinting player from goal-to-goal. The follow through happens as the player sprints from the opposing goal, quickly turning around, at which the overlapping action is evident upon the return of the player to the initial starting position through the entire animation (see Figure 4.8).

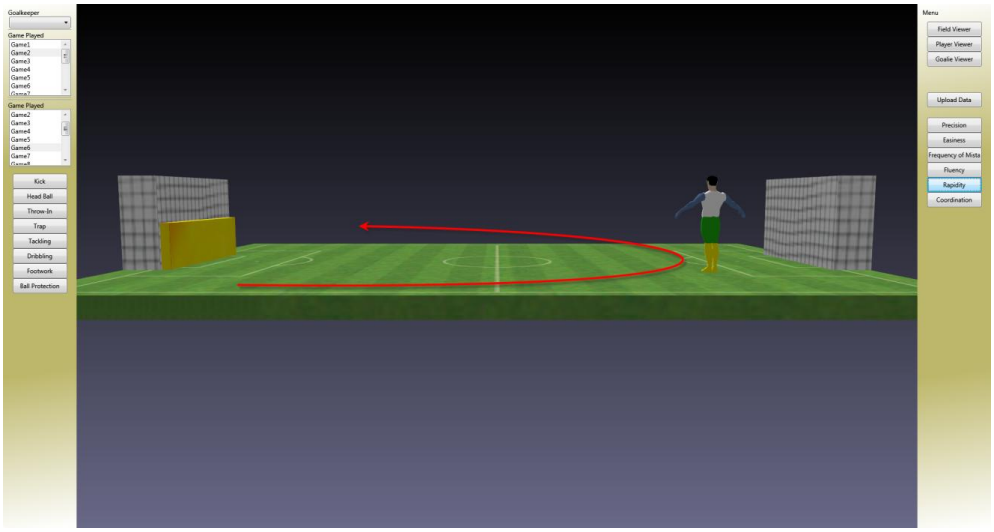

Figure 4.8 The composite of Follow Through and Overlapping actions allows for the representation of the Rapidity attribute of a player. The red arrow is used only for the purpose of demonstrating the path of the animated object.

Similarly, the goalie viewer establishes the same relation between the animation principle described and the rapidity attribute. This can be seen in our goalie viewer by toggling the rapidity attribute, at which a single player is revealed. The goalie player

follows the principle of follow through and overlapping action by running forward from the goal and then quickly sprinting or turning and returning to the goal. The analysis of the rapidity of the goalie player is relative to speed of the sprint for the sequence of the animation.

4.6 Exaggeration

Both the player and goalie visualizations provide a metaphoric relationship between the animation principle of exaggeration and the coordination of a particular player. For the player viewer this relationship is established by the comparative analysis of the erratic motions between two player models. Upon toggling the coordination attribute the field viewer rotates to reveal a top view of the field and two player models that osculate in motion from goal-to-goal; both starting at an initial starting position (see figure 4.9). A motion that osculates less erratically is representative of overall greater coordination, however an extreme erratic movement denotes poor coordination.

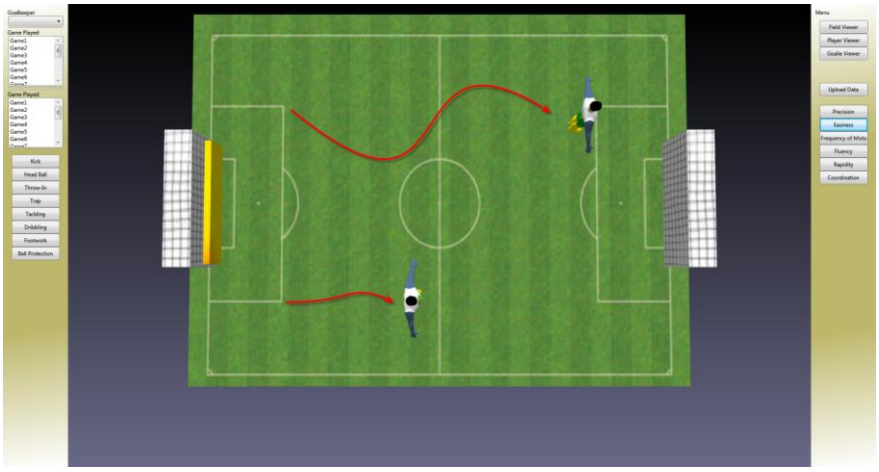

Figure 4.9 Exaggeration animation principle is applied to the player viewer. The oscillation of two players traveling from goal to goal allows for a comparison of coordination between the two players. The red arrows are used only for the purpose of demonstrating of demonstrating the path of the animated objects.

In contrast to how the principle of exaggeration is represented in our player viewer, the goalie viewer establishes the metaphoric relationship of exaggeration and coordination through a sequence of animations that allow for visual analysis of coordination based on presence of an arc. Toggling the coordination attribute within the goal viewer reveals a single player that appears to be jumping to a dive in the motion of an arc. The analysis of this motion is characterized by the overall curve of the arcing model as it attempts to dive. A motion that has a large arced motion is representative of a player that has lesser coordination, whereas one that is less arced and straighter in motion means a goalie player that is extremely coordinated.

Chapter 5

User Evaluation Setup

The testing and evaluation of the usability of information visualization systems has become a new form of research within the interdisciplinary field of information visualization. This chapter acts solely with the purpose of outlining a case study in the event of any continuing research. For any possible future case studies in determining the usability of our developed Soccer Scoop suite of visualization tools and to prove the validity of the visualization techniques employed as it relates to metaphoric interpretation, we propose an evaluation setup based on a new and emerging research method called Multi-dimensional in-depth Long-Term Case studies (MILCs) [26]. This evaluation method is comprised of four main aspects or parts. The first being that it is multi-dimensional in terms of the nature of how we would gather information such as interviews, observations, and surveys. Second that it is in-depth in that there would be an intensive engagement, interaction, or partnership between us the researchers and each of the coaches from different geographic locations. Third is that the evaluation method is long-term and longitudinal based on the number of repeating interactions or observations as studied for different coaches from different geographic locations that will be executed over a long period of time for the length of any future research. Lastly, this evaluation method is a case study in that we would attempt to compose detailed reports on a small group of users that consist of three soccer coaches from different locales. Using this proposed method as a basis and outline for possible future research, we would attempt to answer the question of whether or not our visualization tool is useful for the soccer

coaches for actual real-world performance analysis. Through several multi-dimensional in-depth long-term case studies, we would ultimately attempt to prove that our visualization tool is effective, efficient, and intuitive to perform the actual task of performance tuning within the setting of a normal work environment. By collecting evidence by means of multiple case studies, we would attempt to establish the effectiveness of our visualization tool which would ultimately allow for confidence in the generalization of any future results.

5.1 Case Study Overview

This case study overview acts as an outline to a proposed evaluation setup that can be used in the event of any continuing, future research for determining the effectiveness of our suite of tools. It is proposed that the case studies should be longitudinal and should be performed by "real-world" soccer coaches from three different countries that include, but are not limited to, Romania, Brazil, and USA. We include these specific countries in our proposed outline as we have either already developed an established relationship, in the case of our initial collaboration with the University of Craiova, or have already attempted to establish relationships with Soccer coaches from these regions during the early stages of our research; as in the case of both Brazil and USA. The soccer coaches should be directed to collect actual data and then begin leveraging our visualization tool to explore the data within their usual environment under normal working conditions. Before beginning each case study, it is a requirement that we would first familiarize and understand the dynamics surrounding the game of soccer such as how the coaching system works, what goals provide for successful outcomes, and other specifics that are

critical establishing appropriate observation and interactions throughout the case study. It is then necessary to establish interactions with coaches in order to collect both qualitative and quantitative data that will be used during the analysis of the final results [27]. These include the gathering of questions, usage data as established by using our tools, or actual raw performance data. We will then perform an analysis against the gathered data using a database or other analytics tool. Lastly, we will attempt to make correlations against the results based on each coach and between each region and establish reports that will ultimately prove the effectiveness of our tool or perhaps reveal any modifications that may be necessary.

5.2 Identifying the Sample Group

During the dawn of our research, we had initially planned on establishing collaborations with other regions in additional to the University of Craiova; however time did not permit to solidify agreeable collaborators. To add value to our research, we had planned on focusing on regions that truly represented the game of soccer. With that in mind, we decided that Brazil was a great candidate during our initial plans for establishing future sample groups. In addition, we chose to possibly include USA as a region both for convenience of any possible future collaboration and also for brining value to our research. Although we have merely set the stage for additional collaborators, we keep these sample groups as a focus to our proposed outline to the readers. In the event of a future case study, we would be using the multi-dimensional in-depth long-term case study method for several longitudinal case studies that would initially involve possibly three, but not limited to, different soccer coaches existing in possibly three

domains of different countries that would include, ideally, Romania, Brazil, and USA, 2 data sets for goalie and players, and 3 different visualization tools that include the "Field Viewer", "Player Viewer", and "Goalie Viewer". The application context of all proposed longitudinal studies would exist with each of the coaches' actual working environment. The coaches that are involved within the longitudinal case studies should have no prior experience with the Soccer Scoop suite of visualization tools and are should not be biased by the research. Following the steps that we have described above should allow us to observe similar interactions within our suite of visualization tools between the sample groups (three if initially possible), thus providing results that would be much more generalized.

5.3 Duration of training, interviews, and observations

The multi-dimensional nature of the case study we have outlined in this chapter would ideally consist of several remote interviews/meetings in order to train each coach on the visualization techniques of the tool and to gather further insight on the progress of the study or to act as a support for questions that may arise during the study. Additionally, the periodic remote interviews/meetings would allow for the gathering and defining of the high-level questions by each coach within the sample domain that pertain to specific goals resulting from player/goalie performance analysis. The case studies would be long-term as they would be held over the length of several games or perhaps a complete season. Following the steps described above are necessary in proving the effectiveness of our applied visualization techniques and whether or not our tool would

be powerful enough for accurate statistical analysis as it relates to overall soccer player performance.

5.4 Gathering data for Analysis from disparate sample domains

Each longitudinal case study should be performed for an extended period of time or season based on the series of games or an entire game season and will be conducted within the chosen sample domains (ideally focusing on Romania, Brazil, and USA as pivot groups if possible) each with an experienced soccer coach. The data that would be analyzed by the coach is both player and goalie data for a variety of different player performance attributes. The main high-level goals as established in the event of this outlined case study should be defined by several questions that would be defined by the coach prior to leveraging our suite of visualization tools. For example, is the goalie player better at home or away, is a specific player in need of a performance improvement, will these tools allow for successful team building, can overall team performance be enhanced, etc. Additionally, the interactions between the coaches and the various features of our tools would be documented and should be in the form of brief descriptions or comments as related to each usage session.

5.5 Results Analysis Outline

For each longitudinal case study as outline in this chapter, we would need to classify any collected results into four categories as proposed by others who have leveraged the multi-dimensional in-depth long-term case study approach [28]. First would be an analysis on the high-level questions that have been established by each coach from each geographic

region. Next would be the level of success that has been achieved by the coaches upon usage of our tool within their setting and if there has been actual benefit with using our tools. Third would be the interpretation or identification of any possible discoveries that have been found resulting from analysis of the collected usage data by the coaches. Lastly, we would need to formulate an analysis of how the coaches adapt and interact with the established metaphors in our visualization tool and would then compare difficulties, issues, problems, or complaints found between each sample group domain.

Chapter 6

Conclusion and Future Work

Despite technological advances throughout the years, it has become quite apparent that there still exists a void for the use of technology by team managers and coaches in the field of sports, especially within the sport of soccer. This thesis has presented two distinct visualization tools that attempt to assist soccer coaches in the analysis and interpretation of soccer player and soccer goalie statistics by providing a familiar, metaphoric representation of the collected data. It also covers enhancements such as the application of animation principles to improve the power of the visualizations. Finally, a proposed user evaluation setup is outlined for the purpose of recommending a possible future case study that will ultimately verify the effectiveness of our tools.

The first visualization tool presented was called Soccer Scoop, a visualization tool that is made up of two distinct viewers; a field viewer, and player viewer. Both the field viewer and player viewer visualizations fulfill the need of player and player-to-player comparisons relating to overall team performance and dynamics respectively.

The second visualization tool presented was a goalkeeper visualization that is specific to goalie player performance analysis. It was developed as an extension to the existing suite of tools available within Soccer Scoop and allows team managers to compare vital statistics of an individual goalkeeper between other games which they have played or even allows for the comparisons of two distinct performance attributes for the same game. It also allows for distinct player analysis between the same team and different teams for the same game or different games.

Next, several animation principles are applied to both the player and goalie viewers. This has allowed us to enhance the overall effectiveness of our visualization tool by providing a better connection between the metaphoric representation of the data and the performance attributes which the data describes.

Lastly, we propose an outline to an evaluation setup based on a new and emerging research method called Multi-dimensional in-depth Long-Term Case studies (MILCs). This is outline use used as a basis to a recommended future case study that may determine the overall usability of our developed Soccer Scoop suite of visualization tools and possibly prove the validity of the visualization techniques employed as it relates to metaphoric interpretation.

The visualizations presented and discussed in this thesis ultimately achieve the goal of presenting soccer player and goalkeeper data metaphorically to the team manager. Metaphors, as established within these visualizations, minimize the cognitive effort required by the coach when interpreting the collected data.

Soccer Scoop has been developed into a suite of visualization tools for soccer team mangers and currently exists as a fully featured distributable package. It was originally developed leveraging a Java implementation of OpenGL called JOGL. Although this sufficed for establishing an initial prototype during the dawn of our research it was not the appropriate framework for the implementation of a final production product. We chose to redevelop the visualization tools from the ground up using the C# programming language and Windows Presentation Foundation (WPF) as our development platform as it provided a consistent, unified programming model for building Soccer Scoop as a next generation software suite. This transition from

frameworks has allowed for much greater benefits as it relates to overall scalability, reliability, and maintainability of our final product. For example, the performance of Soccer Scoop is automatically optimized via the .NET runtime on any DirectX enabled graphics processing unit (GPU). This allows our application to run fast and efficient regardless of the specifications of the GPU of the client machine with DirectX capabilities.

The current state of our suite of visualization tools holds great potential for future improvements. One of the current deficiencies of Soccer Scoop lies within the gathering and input of data. Although we have refined the data input mechanism in the latest release, one proposed enhancement to Soccer Scoop would be in the development of some kind of real-time data interface via marker or marker-less motion capture techniques. Alternatively, other proposed methods such as with the use of accelerometer and/or gyroscope devices worn by the players could also allow for similar refinement to the input of data. The implementation of either would require Soccer players to wear a device during a game or practice session at which then the data would be sent and gathered wirelessly to the Soccer Scoop application via the client device of the team manager.

As it currently stands, the deficiency not only lies within the collection of data, but within the delay of the interpreted results during analysis as the coach must collect data and then input it later which in turn may create a disconnect or void between what the coach had originally observed earlier with the actually resulting data. Implementing the new input feature previously described would allow for team managers and coaches to provide on the spot, real-time analysis of the performance attributes of players

ultimately allowing them to be more connected to the player allowing the coach to correct any possible deficiencies as they occur.

Another proposed future feature would be in the reimplementation of Soccer Scoop into a mobile form factor. With the dawn of the rise of tablet computing and mobile computing in general, it makes sense that Soccer Scoop exists in a more mobile and portable form as to fit better into the more active lifestyles of coaching and allow for data that can be analyzed during a training session or game already in progress. Coupling a tablet version or mobile version of Soccer Scoop with the feature of the real-time interface described would allow for the greatest level of transparencies with regards to the integration of our suite of visualization tools as it applies to soccer coaching or coaching in any sport.

Moreover, as it currently stands the Soccer Scoop application does not yet possess a proper data model in terms of how data is stored. A proposed feature would be to build and include into the Soccer Scoop foundation a data model that is normalized into a well-defined relational database. With this feature each player can be related to data specific to a game or serious of games in a one-to-one or one-to-many relationship. Ultimately, this would allow for coaches to establish trends of data in attempt to monitor the progress of individual players or the entire team over the course of a series of matches.

Last but not least, as we have focused much of our attention within the realm of Soccer, the metaphoric techniques as applied to our research within these tools can also be applied to other sports especially within the realm of sports medicine. A proposed project would be to adapt the visualizations as described in this thesis into a tool that is clinically based such that it could be leveraged by a Sport Medicine Practitioner. By

implementing more fine-grained detail within our existing visualizations that correctly and accurately represents the anatomical motion of a player based on gathered real-time data, the physician would be able to provide an analysis on the onset or cause of an injury. Such implementation would be included into the player models within our visualizations and would possibly describe general, appropriate anatomical motion that can be used by Sports Medicine Practitioners for the detection of anomalies in technique that could otherwise lead to physical harm such as angles between two body parts, rotating body parts, forearm rotation, surfaces of both hands and feet, bending of the feet and knees, or other general motion. The inclusion of this feature within our current implementation would allow for either Soccer team managers or Sports Medicine Physicians to use our implemented visualization tools within the Soccer Scoop suite. Ultimately, Soccer Scoop could potentially be packaged as a single, integrated product solution that could accommodate both coaches and clinicians alike thus our implementation would prove to be quite powerful within the fields of sports and sport medicine.

Establishing and employing data representation through metaphors is extremely powerful when considering the fast paced nature of coaching within soccer or any sport. Developing a tool that is adaptable within an actual coaching environment is challenging as there needs to be a proper interface that not only displays data, but translates the underlying data into something that is both intuitive and familiar. This data transparency is made possible within our tools by encapsulating and representing a complete set of skill-set categories centric around both player and goalkeeping with their associated attributes and cross referenced elements by establishing both a player field model and

goal model that uses natural objects to represent the data. Our research has shown that if applied correctly and uniquely, the use of metaphors will allow for a quick observation and analysis of the data. By adopting our visualization tools within a coaching setting, if only to supplement their current method of analysis rather than replacing it entirely, coaches will be empowered with the ability to evaluate both player and goalkeeping more accurately with a total focus on both performance qualities or deficiencies. Additionally, they will gain the ability to categorize players or perhaps formulate better strategies that will lead to overall team development and success that will not only allow a coach to establish better control of their team, but perhaps allowing them to possibly predict the outcome of the game.

The visualizations presented in this thesis are great models for how to effectively and appropriately apply the various concepts within the interdisciplinary field of information visualization. Our research may be followed as a basis when attempting to establish metaphors relating to the development of unique, intuitive, and adaptable user interface experiences. Although the suite of visualization tools that comprise Soccer Scoop has been developed for research purposes alone, it is has been developed into a fully featured, distributable software solution that could quite possibly be marketed and sold to soccer coaches and team managers in the near future.

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Appendix A

Glossary of Terms

Attribute-

As it relates to the game of soccer, a quality or characteristic that is associated to a specific player

Ball Catching-

As it relates to the game of soccer, refers to the goalkeeper's skill in gaining control of the ball by using their hands to catch the ball

Ball Kick-

As it relates to the game of soccer, refers to the skill of being able to direct the ball into a specific position or direction

Ball Protection-

As it relates to the game of soccer, refers to the quality of how the player protects and controls the ball from the opponent by using their body

Blocking-

As it relates to the game of soccer, refers to a skill at which a goalkeeper can prevent the ball from reaching the goal

Boxing Ball-

As it relates to the game of soccer, refers to a skill at which a goalie punches balls that cannot be caught

Coordination (motor coordination)-

Body parts such as limbs that all work together in order to perform a well timed, efficient, and smooth motion with respect to a specific action or goal

Details on demand-

As it relates to information visualization, a technique that allows the interactive selection of specific parts of data to be visualized in a more detailed view while still keeping all the data elements into focus

Diverting Ball-

As it relates to the game of soccer, refers to the goalkeeper's ability to divert the ball using their body back into the field to a specific direction or player

Dribbling-

As it relates to the game of soccer, refers to the skill that allows a player to advance the ball down the field and past their opponent with their feet

Easiness-

A characteristic of a skill in soccer that is capable of being accomplished with great ease and having no difficulty to perform

Execution Mechanics-

As it relates to the game of soccer, refers to quality of how a player executes a particular skill

Feign for Footwork-

As it relates to the game of soccer, refers to the act of fake kicking the ball with inside of the foot

Fluency (automaticity)-

Fundamental skills that are "automatic" and require little or no conscious attention

Footwork-

As it relates to the game of soccer, refers to the many skills related precisely controlling the ball with the feet for both passing or defensive purposes

Frequency of Mistakes in Execution (in soccer)-

As it relates to the game of soccer, refers to the number of errors or mistakes in executing a particular skill

Gestalt Principles-

Refers to a term in psychology called Gestalt which implies "unified whole" and is centric to the theories of visual perception at which describe how a user may organize and group various visual elements through the use of certain principles such as similarity, closure, continuation, and proximity of visual objects

Glyphs-

As it relates to information visualization, refers to a graphical object or symbol that is designed to represent the values of specific data

Hand Throwing-

As it relates to the game of soccer, refers to a skill at which a goalie will throw a ball back into play to a specific direction or player after being caught or picked up

Head Ball-

As it relates to the game of soccer, refers to the act of controlling the ball with the players head in order to pass or redirect a flying ball to another player or for the purpose of defense

Likert Scale-

Refers to a rating scale that is commonly used for scaling performance statistics in survey based research

Lunge-

As it relates to the game of soccer, refers to the skill at which a goalkeeper will rush suddenly toward the direction of an oncoming ball for the purpose of defense

Precision-

A skill quality that is both exact and accurate when performed

Rapidity (speed)-

Refers to the synonym for "speed" in English and implies moving or appearing to have great speed

Tackling-

As it relates to the game of soccer, refers to skill of the stealing of the ball away from the opponent

Tactical Utility-

As it relates to the game of soccer, refers to how a player utilizes all of their skills with regards to attacking or defending the ball

Throw-in-

As it relates to the game of soccer, refers to a method of restarting the play of a game after a penalty by a player throwing a ball directed a teammate on the field

Trapping-

As it relates to the game of soccer, the ability to take a ball out of the air and get it to the ground as quick as possible

Star Plots-

Refers to a method of displaying multivariate data values that are each related in a sequence of spokes where each spoke represents a single variable and the lines that connect each data value resemble the shape of a star

Slow Execution of Movement-

As it relates to the game of soccer, refers to the skill related to the quickness of movement for either player or goalkeeper as it applies to performing a technique

Visualization Tool-

As it relates to information visualization, refers to a software system that may use a visual, graphical display, allowing a user to form a mental model of the data by changing the view of some data through various interactions with the system