Towards Classifying Visualization in Team Sports

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Abstract

Visualization and team sports have an important and established relationship that is seldom understood. Team sports can be considered as complex activities containing a considerable number of abstract datasets and participant categories, such as athletes, coaches, referees and spectators. This paper proposes that the field of visualization has been applied within team sports in various ways to provide these participants with representations of these datasets. This has resulted in data-augmented games which are easier to play, judge and watch respectively.

This paper provides a review of past and current applications of visualization within team sports. A model is presented to classify sports visualizations along conceptual axes. This model will allow future or potentially untapped applications of team sports visualization to be identified and classified.

1. Introduction

Visualization has been connected with different meanings within different contexts. Many areas offer detailed descriptions for visualization. For instance, scientific visualization is the use of visual images that aid the understanding of complex scientific concepts [1]. Information visualization is the visual representation of abstract data to amplify cognition [2]. So-called non-visual visualization is the use of human senses other than sight to convey data, such as sound and touch [3]. In effect, the field of visualization includes: information graphics, the images such as maps, charts and cartograms used to represent data [4]; as well information design, the communication of information for efficient and effective use through visual narratives within an illustrated context [5].

Team sports are a fundamental constituent of society today, available through almost every modern communication medium. They can be viewed on television, heard on radio, read in newspapers, and followed via the internet or mobile phone. Unlike individual sports, team sports require the collaborative involvement of multiple participants simultaneously. For this to occur, all participants must posses a synchronous understanding and global overview of the game-play aspects. As team sports naturally become more complex over time, such as with the regular introduction or modification of rules and regulations, they become increasingly difficult to understand. Different forms of visualization have been applied to solve this problem.

The conceptual use of visualization within team sport can be broadly interpreted. It is applied in a variety of ways; from scientific representations of physical quantities such as motion and trajectory, to the more contextual representation of game rules and team identity. This wide approach to visualization methods can be attributed to the abstract nature of the data. Team sports visualization is thus described as any representation of game-related data which supports the understanding of its participants; where game-related data refers to any information or dataset which affects or directly results from game-play.

By visualizing specific aspects of team-sports, the games have become more comprehensible. For example: colors and numbers have allowed athletes and teams to be identified; field lines and marking have enabled rules to be followed; while more recently advanced computer generated graphics have allowed even the most complex sports data to be understood by a range of non-expert television viewers.

However, when implementing visualization within team sports, two issues arise. Firstly, decisions need to be made such as: what data should be shown, how to show it, and who to show it to. Secondly, it is important to address whether there exists any need for it. Therefore, any sports-based visualization development needs to be justified. Little research has been undertaken to identify the varying applications and methods of visualization within team sports. This paper reviews these, and uses the findings to produce a conceptual model which can be used to explore, describe and identify current applications and to discover novel, still untapped opportunities.

2. Visualization in team sports

The use of visualization within team sports can be divided into three categories:

- **Athlete-centered**, which focuses on supporting the athletes as well as coaches.
- **Spectator-centered,** which supports the spectators or audience.
- **Judgment-centered,** which is geared towards the accurate, fast and effective judgment of team sports by one or more official referees.

In the following sections, several past to present cases and research of the use of visualization within team sports will be reviewed. This paper highlights four main areas within the team sports domain where visualization has been applied: a) clothing (e.g., uniforms, player numbers, etc), b) environment (e.g. court, field, etc), c) media (e.g. billboards, augmented television broadcasting, etc), and relatively recently d) wearable computing (e.g. sensors, tangible displays, etc). Each of the cases discussed are able to be classified as either: athlete-centered, spectator-centered or judgment-centered visualizations.

• **Clothing.** It may appear not obvious at first sight, but team sports uniforms can be considered themselves as a form of visualization. Mainly employed as a technique to discern between different teams on the playing field, the use of visualization in uniforms has expanded to represent information about the identification of a single athlete or team both during and after game-play.

Three of the most conventional forms of existing clothing visualization in team sports are:

- **Numerical** depiction provides a visual means to identify the position of a player. The first record of the use of numbers in team sports was in 1928, where the competing English Football teams wore numbered shirts [6]. Prior to this the only way to identify a player was to refer to a provided match itinerary.
- **Color** helps to give a team a pre-attentive identity. The first sporting teams in the 1800's chose their colors based on tradition [7], thus color visualized information about their unique heritage. While heritage is still a leading factor, teams today sometimes choose their colors based on psychological factors. For example, the color red is believed to represent dominance or aggression [8].
- **Name Identification.** In some team sports there are no specific rules against players of the same team having the same number. So as teams began fielding athletes with the same number, the use of a textual graphic became another method to distinguish between athletes. In addition, these graphics sometimes tend to include the name or logo of the athletes team.

• **Environmental.** The physical environments (courts, fields, etc) in which sports are played serve as an additional application for visualization. Graphical symbols and images break a playing area up into sections. These static graphics constantly communicate various kinds of information about a sport to the athletes, judges and spectators alike.
Different environmental symbols in team sports reveal different information, but ultimately they all visually represent the strict rules of game-play. Lines around the perimeter of a playing field represent the boundaries; locations which if crossed by an athlete during game-play result in some sort of punishment. Recurring lines break a playing field up into sections; dictating locations where certain players can and cannot enter. While special lines, usually at the two ends of the field define the goal areas; identifying locations athletes must reach to score a point. Figure 1 is an example of a common team sports environment.

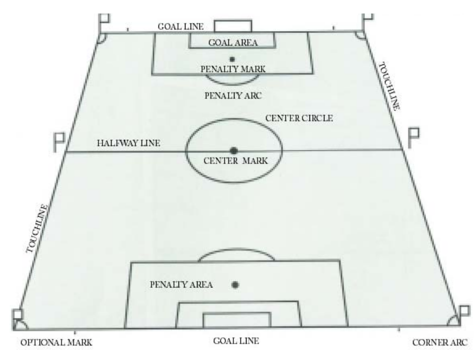

Figure 1. Common Soccer environment [9]

• **Media.** A large majority of the innovation and application of visualization within team sports has occurred within the area of media, such as: print, television, radio, and the internet. This area is primarily targeted at supporting spectators, so can be further divided into two categories: local and remote.

Screen annotation is one of the most widely observed cases. This involves the use of superimposed computer graphics over live sport broadcasts, such as the virtual line which simulates the current world record and accompanies athletes during a televised race (see Figure 2). Virtual Spectator [10] is another advanced visualization system which allows for data-enhanced replays of entire team sports events for remote spectators. Similarly, LucentVision [11] tracks and visualizes the movement data of tennis balls and athletes in 3D virtual space.

Figure 2. Virtual world-record-line [12]

The early use of scoreboards - devices used to visually track team sports game activity and running score - has led to the development of an entire range of team sports visualizations which display a variety of statistical information, here named *activity history*. These are best described as the graphical representation of both past and present game-related information of a sporting event simultaneously. Cases of these are: performance graphs which report on the physical activities of an athlete or team throughout an event [13]; game-flow charts that graph binary data such as points scored over time; shot charts that map particular actions to an environmental graphic [14]; and Sparklines [15] which are small, high-resolution, data-intense graphics that display sports activity over time.

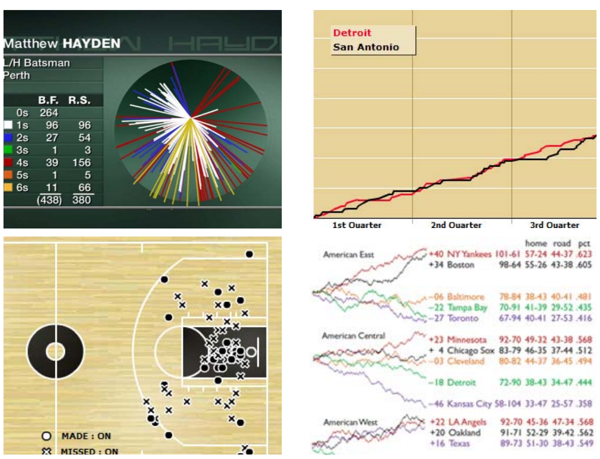

Figure 3. Clockwise from top left: performance graph [13], game-flow chart, shot chart [14], and Sparklines [15]

The ability of this kind of visualization to provide a global overview of a team sports event is highly favored. Either when team sports are in play or after they have concluded, the remote participant is often interested in obtaining only a summary of the game which highlights key events. Activity history visualization of team sports has satisfied this need by providing a means to obtain necessary game information all-at-once. This is apparent with cases such as the season statistics system [16] which can provide entire seasonal NBA data within a single data visualization. It can also be used to offer specific judgment support, as is the case with Pierro [17], an event tracking visualization system for adding tracing graphics to team sports replays for error detection.

Non-visual cases of visualization have also been utilized within this media area. For instance, the Cyclops Auto Serve Line Detector for tennis [18] uses sound tones to convey judgmental information, as it detects if the athletes serves are acceptable. Devices such as these have paved the way for tangible forms of team sports visualization.

- **Wearable Computing**. This area refers to more recent devices which are worn on the body of team sports participants and are used to deliver or transmit forms of visualizations. They are usually small and undetectable technologies, and therefore have been able to be integrated into many sports with little change. The tactile vest is one such case of wearable computing visualization [19]. The vest is fitted to rowing and skating athletes, and like the Tennis Auto Serve Line Detector [18] it uses a multi-modal visualization channel, in this case the sense of touch. The vest is used to coach and train athletes using vibration to encode physical performance information.

The majority of these technologies are sensor-based, which allow measurable physical properties to be visualized in real-time in order to increase immediate understanding and improve the athlete's performance accordingly. Force sensors integrated into body protectors can detect the amount of force delivered to an athlete, which is then transmitted and visualized as point values on a scoring display for more accurate adjudication of martial arts events [20]. Motion sensors for downhill professional skiers reveal body movement information which allows athletes and coaches to optimize their routines for maximum performance [21]. Tracking sensors are used for visualizing athlete performance for team sports which occur over large distances and are difficult to attend. The Internet-enabled wearable sensor technology attached to cross country skiers allow officials and remote spectators to visually observe athlete progress and body vitals, making such sports more accessible than ever [22].

Wearable computing for sports purposes includes technologies which can be carried and worn by spectators. TennisViewer [23] is portable and handheld computer device which is able to visualize the data representing a tennis game, increasing a spectators understanding.

3. Team sports visualization model

This conceptual model has taken into account twenty different cases of team sport visualization which are utilized during game-play. The goal of this model is not to be exhaustive, but rather to cover the most important areas of contemporary team sports data representations, which in addition showcases a variety of current applications and research.

This model is designed to allow any team sport visualization to be described, and so can be used on past as well as future applications. It has been visually represented here to obtain a structured breakdown of its current state and usage.

- **Model Outline.** The framework outlines four different visualization classifiers: Data, Form, User, and Area. Each of these classifiers themselves contains sub-classifiers:

- **Data** refers to the abstract quality or quantity that is being visualized. It includes the sub-classifiers: identity, rules, performance, and physical activity.

- **Form** describes the visualization method used, including the sub-classifiers: identification, textural, abstract, and scientific.

- **User** is the participant type for whom the visualization is intended: athlete-centered, judgment-centered, local or remote spectator-centered.

- **Area** refers to the four areas within team sport in which visualization can occur. These are: clothing, environment, media, and wearable computing.

- **Model Presentation.** Each team sports visualization case is added to the model based on its applicable classifiers. Through populating this model, a means is provided by which to compare a large number of these cases based on a common framework. This can allow similarities and gaps within this field to be identified. The model is represented by a 3D 'loaf' consisting of four different slices, within which each case is plotted (see Figure 4).

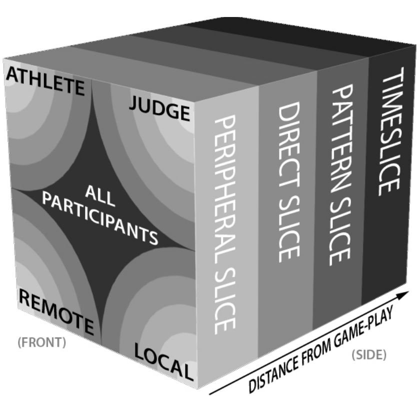

Figure 4. 3D loaf model

The user classifier is mapped onto the front face of the cube (X and Z-axis). Each corner of the face denotes one of the four user sub-classifiers. A Distance from Game-play value is measured along the length of the cube (Y-axis). The data/form classifiers, which go hand-in-hand, are merged and mapped to color, as specified by the legend in Figure 5. Similarly the area classifier is denoted by pictograms, also in Figure 5.

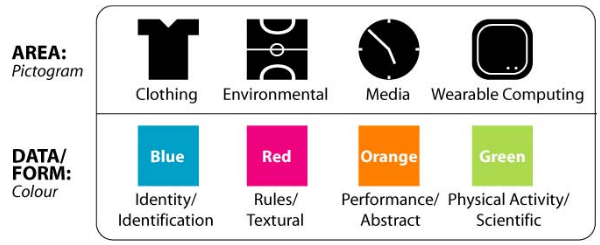

Figure 5. Model legend

- **Model Population**. Individual cases are plotted within the multi-dimensional front view, which is divided into four quarter-circle zones. Each zone refers to the predominant user classifier of that zone, and so each case is placed in a corner based on its primary user. The cases are then moved around within these zones depending on their relationship with surrounding zones; with the centre zone, labeled as the all participants zone, containing cases applicable to all users (see Figure 6). The values of these relationships were determined based on a similarity matrix of all cases, which took into account measurements of the distance and usage-time of every case from the perspective of each user.

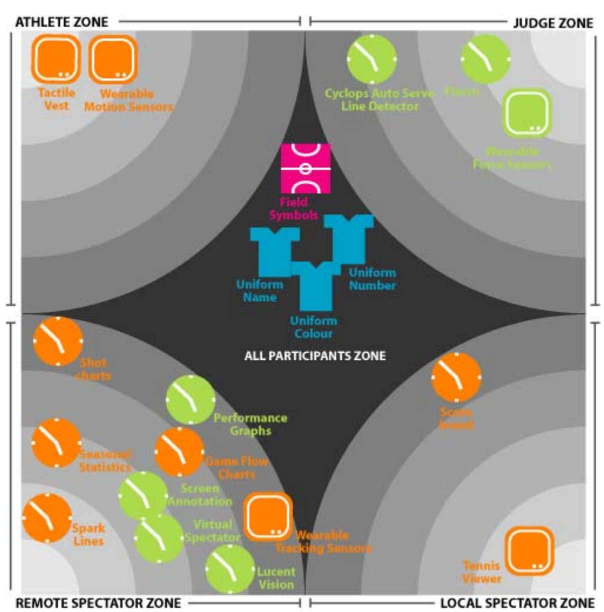

Figure 6. Front view

One can perceive four distinct perception slices. Within the side view (see Figure 7), Four different slices along the Y-axis refer to how information is recognized and extracted from the visualizations in order to be understood. The peripheral slice refers to cases that are sensed immediately, without the need for direct attention; direct refers to those which must be viewed directly for understanding; pattern refers to those cases understood via the recognition of certain patterns; and cases in the time slice are those recognized only after comparing or placing them within a historical context.

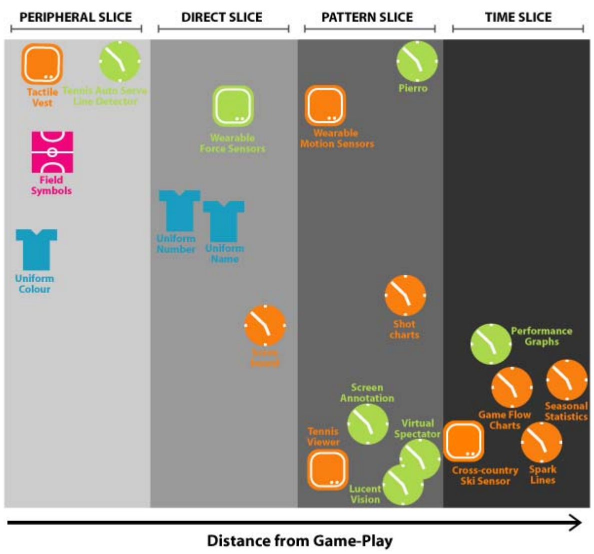

Figure 7. Side view

4. Discussion

The front and side views of the conceptual model allowed certain visualization trends and gaps within team sports to be identified. Firstly, from the front view clustering is clearly evident within the five zones. It can also be perceived that there are very few cases which directly support the athlete. Those cases which do appear in the athlete zone, the Tactile Vest [18] and Movement Sensors [20], are training visualization tools, and cannot be used within game-play. The cases which an athlete can use within game-play all appear within the All Participants Zone, indicating that they are equally supportive to all team sports participants. These cases are also mostly wearable (clothing) visualizations. It is hence found that any visualization which occurs at the centre of game-play needs to be not only athlete-centered, but judgment and spectator centered. However, as color denotes the kind of information shown, and they are primarily blue, it is apparent that this zone is lacking visualization cases both in terms of data type and form.

From the side view, it is found that visualizations which occur close within the vicinity of game-play usually convey information needed for success, such as rules and identity, and hence need to be understood quickly. These cases can be experienced peripherally. However, such visualizations which make use of ones peripheral understanding are currently lacking in team sports, both in information and quantity. The majority of cases occur within the pattern and time slices; however these cases remain inaccessible to athletes.

Many researchers have outlined the acceptance of new technologies within the sporting as always being a complicated process [20], [24], [25], [26]. Particularly with visualization technologies, concerns arise such as: what information is represented, how it is presented, and who it is presented to. Using this model, the state of visualization in team sports was able to be assessed.

- **Relationships identified**. The model provides a visual analysis of the interrelationships between currently established team sports visualizations, allowing trends regarding the use of visualization in team sports to be seen. Four distinct participant zones reveal which visualizations target which users and by what means. Another four perception slices group the cases based on how they are perceived by these users.

- **Gaps identified**. Primarily almost all the cases of team sport visualization are media related and focus on supporting the remote spectator. None at all specifically support the athletes themselves, and few support judges and local spectators. Remote participants receive vast information on the performance and physical activities of team sports games; information which is often hidden from the athletes, judges and local spectators. The domain is therefore currently lacking in visualization cases which target primary participants such as athletes and judges. Those cases which do exist are ‘information weak’, introducing no new information to these participants.

- **Future applications**. Different areas for potential future uses of team sport visualization are recognized. Firstly, the gaps, or zones, in which cases have not been applied or are lacking, are identified as suitable areas for future research. Secondly, wearable visualizations such as clothing and field symbols are among the most successful within team sports. Not only are they targeted at all sports participants, they are able to be recognized via ones peripheral vision; thus understood quickly and easily.

There is observable success resulting from the application of visualization within team sports, as is evident from the numerous cases discussed by this research. With these results, specific progress can be made by investigating whether there is an actual need for filling the gaps that were identified in ‘future applications’. For instance, surveys could determine whether team sports players feel that visualization could augment game-play in some significant way.

5. Conclusions

A review of visualization within team sports was presented. This included past and present applications as well as more recent research endeavors by various researchers in multiple scientific fields. Using the information obtained from this review, a model was formulated to quantify these visualizations in terms of their data, form, end-users, and area of application. This model represents a current understanding of team sports visualization, and has been used to show significant and meaningful dense clusters and gaps, revealing potentially future research directions.

Future work in this area could extend this model outside of a sports context, to classify and discover uses of visualization within other suitable team-based fields such as business, education, or media.

Visualization is a successful and widely used method for increasing human understanding of various datasets in team sports. As its use continues to evolve, new and interesting applications will emerge within new and different areas. These must continue to support participants and never offer an unfair advantage or hinder safety. If team sports visualization continues to embrace the performance of human talent that is core to team sports, its applications will become more successful and be embraced by more people.

6. References

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