

MatchPad: Interactive Glyph-Based Visualization for Real-Time Sports Performance Analysis

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Abstract

Today real-time sports performance analysis is a crucial aspect of matches in many major sports. For example, in soccer and rugby, team analysts may annotate videos during the matches by tagging specific actions and events, which typically result in some summary statistics and a large spreadsheet of recorded actions and events. To a coach, the summary statistics (e.g., the percentage of ball possession) lacks sufficient details, while reading the spreadsheet is time-consuming and making decisions based on the spreadsheet in real-time is thereby impossible. In this paper, we present a visualization solution to the current problem in real-time sports performance analysis. We adopt a glyph-based visual design to enable coaching staff and analysts to visualize actions and events “at a glance”. We discuss the relative merits of metaphoric glyphs in comparison with other types of glyph designs in this particular application. We describe an algorithm for managing the glyph layout at different spatial scales in interactive visualization. We demonstrate the use of this technical approach through its application in rugby, for which we delivered the visualization software, MatchPad, on a tablet computer. The MatchPad was used by the Welsh Rugby Union during the Rugby World Cup 2011. It successfully helped coaching staff and team analysts to examine actions and events in detail whilst maintaining a clear overview of the match, and assisted in their decision making during the matches. It also allows coaches to convey crucial information back to the players in a visually-engaging manner to help improve their performance.

1. Introduction

Performance analysis is a common practice in sports during matches and training [HB02]. It typically involves collecting laboratory or field data, extracting quantitative measurement, carrying out statistical analysis, and data visualization. One crucial area of sports performance analysis is *notational analysis* [HF97] which holistically studies the gross performance in team sports, such as strategy, tactics, formation, and so on. With such a system, an analyst usually records a video of a match and “tags” the video during the match with semantic notations that mark specific events taking place at a particular time period. This results in a large collection of temporal records of events, from which statistical indicators are computed and visualized using conventional plots. One critical shortcoming in the current practice is the disconnection between the *overview* (i.e., the summary statistics) and the *details* (i.e., actual events in the match) [Shn96]. To seek details on demand, the coaching staff and match an-

alysts have to trawl through the large collection of event records. For post-match analysis, the interaction for “visual information-seeking” is highly inefficient, while for in-match analysis, this is practically impossible.

One important functional role of visualization is to facilitate efficient and effective “visual information-seeking” [Shn96]. Considering the requirements of the users and application environments, the visualization must be delivered in a comprehensible manner that is simple and intuitive to understand whilst also being informative. Glyph-based visualization [War02] is a common form of visual design where a data set is depicted by a collection of visual objects, which are called glyphs. Glyph-based visualizations are ubiquitous in modern life since they make excellent use of human perception and cognition, providing instantaneous recognition and understanding.

In this work, we introduce glyph-based visualization into

the process of notational analysis in sports. We considered a number of design options for the visualization, and developed a collection of glyphs that feature metaphoric visual cues for rapid recognition as well as intuitive visual channels for depicting attributes. In comparison with the tabular form of events, the visualization gives an effective overview of a match that users can interact with to obtain details on demand (Section 5). Since the visualization corresponds directly to the match video, key events can also be replayed to show further details. We implemented our visualization system, *MatchPad*, on a portable tablet device, which enables touch-based interaction with the visualization. We developed a scale-adaptive glyph layout algorithm to facilitate effective transition between different levels of details (Section 6). The work was carried out in close collaboration with an international rugby team, and was used during the Rugby World Cup 2011. It successfully highlighted the effectiveness of visualization in sports analysis, by helping coaching staff to examine actions and events in detail whilst maintaining a clear overview of the match, and assisting in-match decision making (Section 7).

2. Related Works

Ward [War02, War08] provides a technical framework for glyph-based visualization that covers aspects of visual mapping and layout methods, as well as addressing important issues such as bias in mapping and interpretation. Ropinski *et al.* [RP08] present an in-depth survey on the use of glyph-based visualization for spatial multivariate medical data, which is widely used for a number of different medical applications including DTI [KW06], SPECT [MSSD*08] and HARDI [PPvA*09] image modalities. Lie *et al.* [LKH09] describe a general pipeline for the glyph-based visualization of scientific data in 3D along with design guidelines such as the orthogonality of individual attribute mappings. Pearlman *et al.* [PRdJ07] use glyph-based multivariate visualization to understand depth and diversity of large data sets. Chian and Rheingans [CR05] use 2D and 3D glyph-based multivariate visualization to show distribution within the data set. Jänicke *et al.* [JBM010] developed *SoundRiver* that mapped movie audio/video content to glyph visualizations on a timeline. Drocourt *et al.* [DBS*11] examine several glyph-based visual designs for visualizing temporal geoinformation. Our work extends upon related works by presenting a practical glyph-based visualization design study for sporting domains.

Event visualization is still a relative new topic within the community. Parry *et al.* [PLC*11] propose a framework for hierarchical event visualization that encodes event importance, and demonstrate this in application to sports. Jin and Banks make use of treemaps for visualizing scoring results and match statistics of tennis matches [JB96]. With regards to glyph-based event visualization, Pearlman and Rheingans use glyphs for visualizing network security events [PR08].

Suntinger *et al.* [SSOG08] also use glyph-based event visualization to create an *Event Tunnel* for business analysis and incident exploration. Kapler and Wright developed *Geo-Time* that displays military events in a combined temporal and geo-spatial visualization [KW04]. Similar to glyph design, the HCI community has looked at the importance of icon design [Git86], and their learnability [MJ93]. In particular, many modern computer systems adopt the concept of visual metaphors for icon design [CMB98].

Interactive visualization looks at the ability to navigate and interrogate datasets through interaction to improve understanding, for which Zudilova [ZSAL09] presents a state-of-the-art survey. Yi *et al.* [YKSJ07] identify seven key areas for the use of interaction in visualization: select, explore, re-configure, encode, abstract/elaborate, filter, and connect. For the exploration of data, Cockburn *et al.* [CKB09] investigate into different interface schemes for studying the overview and detail of datasets. Chittaro [Chi06] also investigates the use of interactive visualization, however focuses primarily on small-screen mobile devices. With regard to interactive glyph-based visualization, Yang *et al.* [YHW*07] propose a *Value and Relation* display that is designed for interactive exploration of large data sets. Shaw *et al.* [SHER99] investigate new techniques for using an interactive lens to explore a 3D glyph-based visualization. Ebert *et al.* [ESZM96] incorporate two-handed interaction and stereoscopic viewing for the exploration of 3D glyph-based visualization.

3. Requirements Analysis

The work described in this paper was carried out by an interdisciplinary group composed of a sports scientist, a former international-level sportsperson, and computer scientists. We were motivated by the huge potential of using visualization in sports performance analysis during matches and in training [HB02]. For example in rugby, Duthie *et al.* [DPH03] and Nicholas *et al.* [JMJ04] confirmed the usefulness of match analysis and team performance indicators respectively. We worked closely with the Welsh Rugby Union for over 12 months, frequently visiting their training grounds as well as inviting the chief analyst to give talks in workshops. From these close contacts, we learned the strengths and limitations of their current workflow.

The team relies heavily on notational analysis [HF97], whereby a match analyst “tags” various events in the video footage of a match with semantic notations, from which a set of key performance indicators are calculated. Currently there are no automated techniques on the market or in the research literature that are capable of performing such annotation reliably, and this was not the focus of this research. Personal position-tagging devices are normally disallowed in real matches for safety reasons. In practice, trained match analysts are highly skilful in video annotation. With the aid of appropriate software, they are able to rapidly annotate major events as they occur within a match. Detailed annota-

tion, which includes player identification, is normally done off the pitch. As the chief match and performance analyst of the team pointed out, the primary issue is in fact “information overload” as reviewing the annotated data is a laborious task. Current software makes use of conventional plots and spreadsheets that are ineffective for conveying the overview and details of events in a match. It is necessary for visualization to address a number of requirements as follows.

- The visualization must be able to depict most, if not all, annotated events that are stored in a tabular form.
- It is necessary for the visualization to connect each event to the corresponding video footage for further analysis.
- The visualization should facilitate rapid information seeking and in-match decision making for coaching staff and analysts at different temporal granularities of a match.
- The visualization should provide coaching staff with a visual aid for post-match team and player briefings.
- The visualization must be intuitive for the target users, requiring minimal amount of learning and memorization. While an analyst may be willing to make effort to learn some complicated techniques, it is not reasonable to demand the same from the coaches and players.
- The visualization must be suitable for portable devices to be used during matches and training.

4. MatchPad Pipeline

Following the requirement analysis, the development of the *MatchPad* started in February 2011. Figure 1 shows the computational pipeline of the *MatchPad*. The pipeline consists of four key stages: XML processing, event visual mapping, graphical composition and integrated user interface that makes up the *MatchPad*.

The first stage is to process the input data. Using a wireless connection, the *MatchPad* retrieves XML data streamed from the analyst’s workstation. This can be scheduled to perform at set time intervals during a match (e.g., every 15 seconds). It is therefore vital that the pipeline can be executed quickly to handle short update intervals. In the XML data, each event is recorded as an instance, of which a typical match would have in the order of hundreds. Each instance will consist of an ID number, a start time, an end time and a name (e.g., scrum). This is then followed by a series of text tags that contain descriptions such as whether the event was won or lost, the formation and strategy adopted, the position on the pitch and whether ground was gained in the play. The pipeline is designed to recognise the semantic textual codes specified in a dictionary for a particular sport or application.

The second stage maps the series of recorded events and their attributes to a collection of glyphs. We chose to use metaphoric glyphs to provide intuitive visualization of events. Each glyph may be augmented with additional visual components and channels for different attributes. We detail our design decision in Section 5.

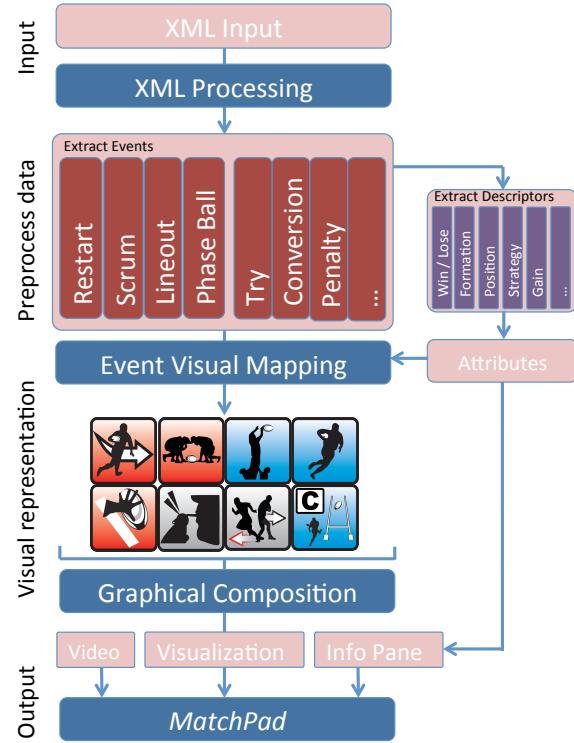


Figure 1: The pipeline used to compute the *MatchPad* visualization. There are four key stages: XML processing, event visual mapping, graphical composition, and the combined video, visualization and information pane of the *MatchPad*.

The third stage constructs a temporally continuous visualization that arranges all event glyphs along a timeline. A scale-adaptive layout algorithm is used to accommodate different levels of detail, which is detailed in Section 6.

The final stage integrates the visualization with the accompanying video and statistical performance indicators to produce the *MatchPad* interface. While the interface allows the user to control all three previous stages, the majority of interaction is zooming and panning for rapid information seeking, forming an active feedback loop with stage 3.

5. Glyph-based Visual Mapping

In glyph-based visualization, glyphs are used to depict multivariate data entities. Typically, each glyph is composed of a number of visual channels, each of which encodes a specific attribute of a data entity. Hence it is necessary to first establish the full extent of the data space. With sufficient knowledge of the data space, one can then explore different design options and make appropriate use of different visual channels in the context of the application concerned.

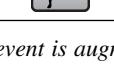
	Match	Team	Player	Outcome	Values	Metaphoric Glyph	Abstract Icon	Shape	Colour
Restart		○		Occurrence					
Drop Kick		○	○	Occurrence					
Scrum		○		Won/Lost					
Lineout		○		Won/Lost					
Ruck		○		Won/Lost					
Maul		○		Won/Lost					
Tackle		○	○	Won/Lost					
Pass		○	○	Won/Lost					
Try	○	○	○	Occurrence					
Goal Kick	○	○	○	Score/Miss	C, P, D				
Injury	○	○	○	Occurrence					
Substitution	○	○	○	Occurrence					
Phase Ball	○	○		Occurrence	1-10				
Territory	○	○		Occurrence	A-D				
Referee	○			Occurrence	N, Y, R				
Ball in Play	○			Occurrence					

Table 1: A range of events are to be mapped in the visualization. Each event is augmented with levels of association (i.e., the match, team or player), and additional attributes (i.e., outcome and numerical and enumerative values). We also illustrate four possible glyph designs: metaphoric pictogram, abstract icon, shape, and colour. We choose to use metaphoric pictogram to represent events in MatchPad.

5.1. Data Space

During the analysis of existing data sets, we identified the set of *event types* and the associated attributes. These include:

- *Levels of Association* — An event is usually recorded in association with different levels of interest, that is, the *match*, a specific *team*, and a specific *player or players*. In some cases an event may be associated with more than one level. During a match, analysts usually aim to record the events at the match and team level in real time, whilst much of the player-specific data is recorded post-match since this often requires repeated playback of the video footage to identify all details of the events. Because of the

importance of scoring events, (e.g., try, goal kick) they are all considered as match-level events.

- *Team Identifier* — A team-specific event is accompanied by an attribute of the team identity. In our application, there are always two teams in a match, referred to as the home team and away (opposition) team respectively.
- *Player Identifier* — A player-specific event is accompanied by the identifier(s) of the player(s) concerned. Here, a player’s number is a unique identifier in each team.
- *Outcome Attribute* — Some events require the recording of an explicit outcome. For instance, outcome attribute for a “scrum” event will state whether the team won or lost. Some event types do not have an explicit outcome de-

fined. For example, a “try” event implies the outcome that the team have successfully scored. We refer those events without an outcome attribute as *occurrence*.

- *Value Attribute* — Some events are associated with a numerical or enumerative value. For instance, a “goal kick” event can be classed as either C, P and D to define “conversion”, “penalty” and “drop goal” respectively.
- *Duration Attribute* — Most events are accompanied by an attribute indicate the duration of the event.

The first column of Table 1 lists most common event types, columns 2, 3, 4 indicates the levels of association, column 5 indicates the outcome attribute, and column 6 indicates the numerical and enumerative values.

5.2. Design Options

Ward presented a number of design options in [War02], all of which were considered in this work. Columns 9 and 10 show two typical design options, namely shape and colour, for representing event types. Whilst these may be suitable for a data attribute with a smaller number of enumerative values, here we find that the number of event types would require many different shapes or colours, which would be very difficult for users to learn, remember, or guess. Considering the captured requirements mentioned in Section 3, we found that it was necessary to explore the design options that were more commonly used in domain-specific visualization (e.g., electronic circuit diagrams) and visualization for the masses (e.g., road signs). Such design options normally feature metaphoric pictograms that are easy to learn, remember, and guess. This led to a decision to base the visual design primarily on metaphoric glyphs.

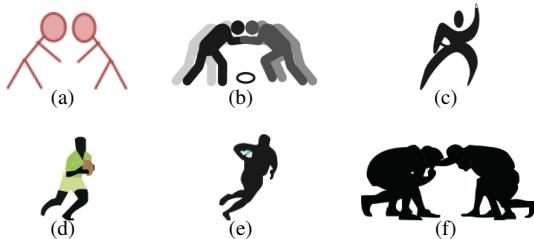


Figure 2: Some designs of metaphoric pictograms. In (a), initial stickmen designs were produced to prompt an artist. The artist produced several different designs: (b) a refined stickman design, (c) a contemporary design, (d) a posterized colour design and (e) a silhouette design. In (f) the scrum is depicted using the silhouette design (cf. (a) and (b)).

Metaphoric glyphs can come in different forms, ranging from abstract representations to photographic icons. We ruled out the abstract representations shown in Column 8 of Table 1 because it would still suffer from the difficulties to learn, remember and guess. We ruled out the use of photographic icons because they would prevent the effective use

of the colour channel for other attributes. Furthermore, the player or team featured in the glyph would at its best attract unnecessary attention, and at its worst would cause some confusion with the actual player and team being annotated. Once excluded both ends of the design spectrum, we considered several styles of illustration as shown in Figure 2. After consulting with the end users, we selected black silhouette as the graphical style of our metaphoric glyphs.

5.3. Resultant Design for MatchPad

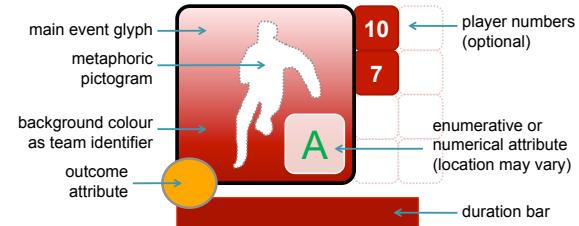


Figure 3: Components and visual channels of the glyphs.

Figure 3 illustrates the spatial composition of glyphs designed for the *MatchPad*. The large square region is the main glyph, which contains a pictogram that represents an event type metaphorically. The set of pictograms frequently used in the *MatchPad* are shown in Column 7 of Table 1.

The background colour of the main glyph is used to indicate the team. The most commonly-used colour convention is red for the home team and blue for the away team. Hence all glyphs that depict events at the team level and player level are coloured-coded in either red or blue background, while all glyphs associated solely with the match-level have a grey background. To further enhance the clarity of the visualization, we also use spatial positioning to distinguish the two teams. Separating by a horizontal time line across the centre of the visualization, all home team events appear above and away team events appear below. This arrangement is designed particularly for this application. In comparison with mingling all glyphs together, the separation makes it easier for the users to identify the formation and tactics of either team, and to focus on the interaction between the two teams (rather than individual players).

As mentioned earlier, player identifiers are normally annotated by the match analysts only in post-match analysis. Hence it is optional to visualize player identifiers in conjunction with an event. If the player identifiers are available, a player’s number is displayed in a small square along the right edge of the main glyph. In addition, this number is also used to distribute glyphs vertically within the team region.

As shown in Figure 3, the duration attribute is depicted by the length of the bar that appears below the pictogram box (in the case of the opposition team this bar appears above

the pictogram box). When a glyph is placed in the visualization along a timeline, the bar length corresponds to the start, duration and end times in relation to the time line. An alternative approach for depicting the duration would be using a clock face [Ber84]. However, this notation would not be as easy to quantify as the duration bar.

Outcome is depicted by a coloured circle placed at the interaction between the main glyph and the duration bar (Figure 3). The circle is coloured in either green or amber to represent success or failure respectively. Since red is already used to represent the home team, there was a question about the multiple uses of the shade of reddish colours. However, because of the strong association between green being successful and red being unsuccessful, we decided to maintain the use of a reddish colour for unsuccessful outcome, but to alleviate the conflict by using an orange shade instead of red. This green-amber scheme allows us to make use of the metaphor of traffic lights. One psychological advantage of using amber instead of red is to make an unsuccessful event as a warning rather than a failure. In addition, by overlaying a circle at the intersection between two rectangular shapes, the design offers further geometric cues for differentiation.

Some events have a visually similar form. For instance, conversion, penalty, and drop goal all involve kicking the ball at the goal. It would be difficult to design pictograms to differentiate these events through different illustrations. It is more effective to make use of textual labels, e.g., C, P and D, in conjunction with a generic pictogram for all three events that defines “goal kick”. In some other cases, there is a need for indicating additional information in numerical, textual or symbolic form, such as showing which part of the pitch an event takes place (territory A-D), different decisions by a referee (no card, yellow card, or red card), and so on. We refer to such additional information as enumerative and numerical attributes. The depiction of these attributes is placed within the boundary of the main glyph, and their locations vary according to the generic pictogram shared by each sub-group of glyphs. The attributes are usually shown in 1 or 2 numerical, textual or symbolic characters. Four colours may be used, three generic colours, black, white, and green, and one team colour, either red or blue. The use of different colours, location and occupation styles, ensures that each sub-group that shares a common pictogram does not share the same visual representation of enumerative and numerical attributes as any other sub-groups. This extra differentiation in visual coding serves as an error detection and correction mechanism as described in [CJ10]. Note that other attributes, such as team and player identifiers and outcome, are also of an enumerative and numerical nature. Because of their frequent occurrence and semantic importance in this application, we created separate visual channels for these attributes.

Although glyph-based visualization is the main focus of this work, we are careful not to overload the glyph-based visual design. In particular, we make use of other visual

designs for depicting information considered to be coarser or finer than above-mentioned events. Since rugby can have many stoppages, we use a pale green background to indicate “Ball in Play” events (shown in Figure 7). This avoids the excessive use of the “Ball in Play” glyph, while providing a clearer overview of the global game pattern “at a glance”.

Rugby is a game that involves much strategic planning and tactical play. Coaching staff and match analysts have a huge interest in the progress of the game play. Analysts normally record a match in phases, each of which typically lasts for 10-15 seconds. A phase corresponds to the time intervals between tackles or similar events during an attack. For example, when a ruck or maul occurs, the previous phase ends and a new phase begins. Initially we considered using a numerical attribute to indicate phase 1, phase 2, and so forth. However, this approach would require the use of many glyphs and rely on the users’ cognitive reasoning to connect different glyphs together to establish a mental picture of phase progression. Because the relatively fine details about the phase are particularly important to the users, we make use of a step-like notation, as shown in Figure 7, to depict the number and progression of consecutive phases in an attack. The steps not only provide a scalable depiction of the number of phases, but also metaphorically conveys the sense of intensity of an attack. As with the event glyphs, either a green or amber circle will appear in the corner to indicate successful or unsuccessful play (e.g., whether the team have managed to push forward and gain territory on the pitch).

6. Visualization Interaction

One of the requirements of the *MatchPad* is to support rapid information seeking, which involves an extensive amount of interaction for browsing and zooming, and requires a very fast layout algorithm to respond to the user’s interactions.

6.1. Interactive Visualization

Since the *MatchPad* is designed primarily for tablet devices, we incorporate intuitive controls for touchscreen interactions. The user navigates forward and backward along the timeline by sliding one finger across the screen, and can make a two finger pinch to zoom in and out of the timeline. To facilitate rapid information seeking, the user can skip by a set time period (e.g., 5 minutes) by tapping two fingers to the left or right of the display. A three finger tap will skip to the most recent event. In addition to this, the user can also expand (or condense) the timeline horizontally using a slider.

There may be occasions where many events occur within a short period of time. When the timeline is condensed, this could result in cluttering and occlusion. Therefore a glyph placement algorithm is required that can adapt the layout quickly to accommodate the new scaling factor. This is particularly important for in-match analysis, when the analyst

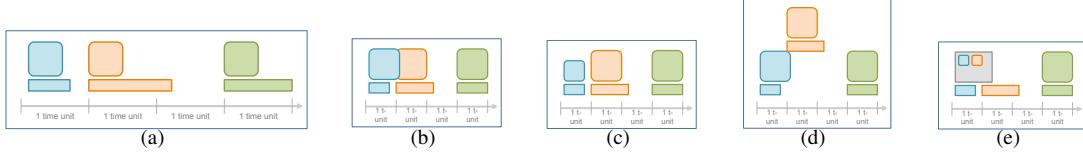


Figure 4: Scale-adaptive layout for key events. In (a), the key events are shown at a scale where no overlap occurs. As the user condenses the visualization timeline for an overview, the algorithm determines the most suited layout for each glyph. In (b), the glyphs are stacked horizontally. In (c), the glyphs are scaled based on their duration. In (d), the glyphs are stacked vertical. Finally, (e) combines two (or more) events to generate a new macro glyph that is used in place.

often needs to glance back at a period of time and then to focus back on the present action.

6.2. Scale-Adaptive Layout

Each glyph is positioned primarily according to the time when the corresponding event took place. Hence in principle, its horizontal position defined by the left boundary of the main glyph box is fixed along the timeline. If player numbers are available in the annotation, we make use of a hashing function based on these numbers to distribute glyphs vertically. However, as mentioned previously, for real time annotation during a match, such information is normally not entered. The glyphs are thus, by default, placed on one of the three lines, namely home team above, match level in the middle and away team below. When a time-line condensing action is performed, the space allocated to each glyph becomes smaller, resulting in cluttering and occlusion. One naive solution is to reduce the size of glyph based purely on the zoom-factor. However, the glyphs could quickly become too small to be understandable. Hence the goal of the placement algorithm is to determine the appropriate size and position of each glyph in order to maintain clarity while preventing serious cluttering and occlusion.

Figure 4 illustrates a typical scenario, where the timeline is condensed to 50% of the original length. So to preserve visual association of events, the visualization is continuously scaled between four transitional layouts (Figures 4(b-e)). Once the given threshold is reached for one layout, the algorithm will query the next layout for additional size and positioning. The four layouts are:

- *Horizontal Stacking*, which maintains the default glyph size and positioning for the current zooming factor, but can introduce occlusion of the events.
- *Size Reduction*, which resizes the glyph based on the event duration and the current scaling factor.
- *Vertical Stacking*, which adjusts the vertical position of the glyph based on the current scaling factor.
- *Macro Glyph*, which combines a set of glyphs into a macro that visually replaces the glyphs within the macro.

Figure 5 shows the algorithm in pseudo-code. We adopted

a deterministic process as it is generally much faster than a global optimization approach. We consider four options in the order of preference and evaluate each option based on the level of occlusion. The algorithm requires several parameters adjustable by the users. They are the minimal amount of visibility for horizontal stacking (MINH_VISIBILITY), scale reduction (MINS_VISIBILITY) and vertical stacking (MINV_VISIBILITY). The visibility values are in percentage of glyph area (by default, 0.5, 0.25 and 0.5 respectively).

Algorithm setScaleAdaptiveLayout(*zoom_factor*)

```

1: display_glyphs_inview()
2: change = false
3: for (each glyph, g[i], in view) do
4:   compute_visibility(g[i])
5:   if (g[i].visibility < MINH_VISIBILITY) then
6:     reduce_size(g[i], zoom_factor)
7:     change = true
8:   end if
9: end for
10: if (change == true) then
11:   display_glyphs_inview()
12:   change = false
13:   for (each glyph, g[i], in view) do
14:     compute_visibility(g[i])
15:     if (g[i].visibility < MINS_VISIBILITY) then
16:       assign_yoffset(g[i], zoom_factor)
17:       change = true
18:     end if
19:   end for
20:   if (change == true) then
21:     display_glyphs_inview()
22:     change = false
23:     for (each glyph, g[i], in view) do
24:       compute_visibility(g[i])
25:       if (g[i].visibility < MINV_VISIBILITY) then
26:         generate_macro_glyph(g[i], zoom_factor)
27:       end if
28:     end for
29:   end if
30: end if
```

Figure 5: Pseudo-code for the scale-adaptive layout.

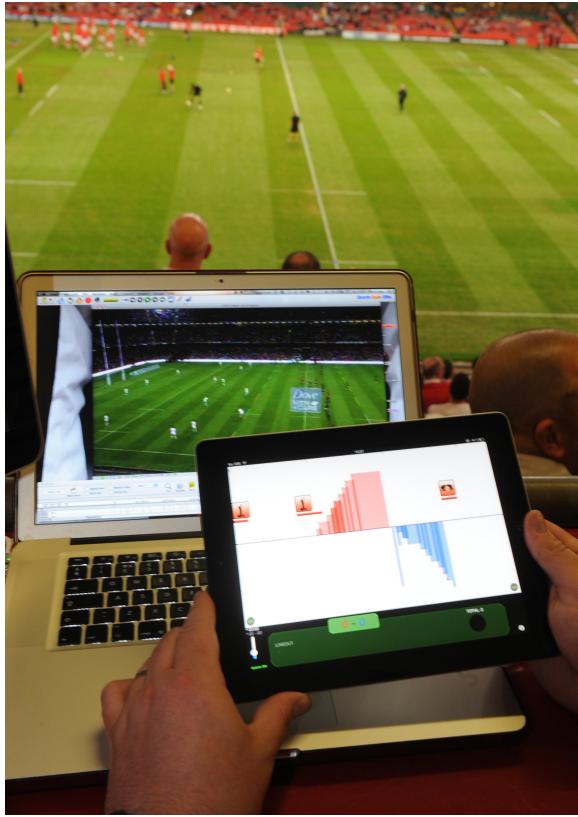


Figure 6: MatchPad being used by the Welsh Rugby Union.

7. Case Study: Welsh Rugby Union

We spent a year working with the performance analysts of the Welsh Rugby Union to develop the *MatchPad*. They contributed to all stages of the design and evaluated the *MatchPad* throughout its development. The primary focus was to deliver an application that would integrate with their current workflow and allow them to visually explore the huge amounts of event records. It also played an integral part during their Rugby World Cup 2011 campaign (Figure 6). Two annotated screen shots are given in Figure 7. After the tournament, the team provided us with their feedback.

“The main thing for us is visualizing the data and visualizing it in a very easy to interpret manner. The major benefit of the MatchPad is that it gives us a good overview of how the game is going, because when you are looking at the game in such detail you lose sight of the big picture. In particular, it is a great tool for oversight when matches are very intense, and for looking at the key instances of the game and how they interact with each other. With the iPad, it is portability. We have it with us all the time so when the coach wants to know something we can see it immediately on the MatchPad.”

Further feedback confirms that the *MatchPad* successfully fulfils all the requirements of Section 3 – providing use scenarios such as in-match focus and context, half-time discus-

sions with players (including access to video) and post match detailed analysis. Most of all, players and coaches are able to use the app with little or no training due to the metaphoric approach taken in the design and the intuitiveness of the software combined with the iPad.

Further evaluation was conducted by means of a consultation meeting with a group of sports science students (5 male and 3 female) with various levels of notational analysis understanding. We focused on three aspects: whether the *MatchPad* improves upon existing systems, the glyph design used for notational analysis, and potential areas of improvement. All participants felt that the summary overview gave greater visual clarity than other notational analysis systems (e.g., SportsCode) and was more suitable for rapid in-match decision-making. Most participants rated it as a significant improvement over existing systems. For the glyph design, all participants agreed that metaphoric glyphs were by far the best approach for representing the events. The metaphoric glyphs were intuitive to interpret, whereas other designs (see Table 1) would require significant learning, causing potential misunderstanding. For improvement, the group suggested that further statistical analysis such as live possession would be beneficial. It was also suggested that spatial information and “off-ball” positioning should be displayed (although this data is not currently collected by notational analysis). Another good suggestion was to show how many events a player has been active in, so to highlight the possibility of fatigue and need for substitution. Finally, the group felt that the *MatchPad* could easily be used in other team sports such as football, netball and hockey. We are now working with a Championship football club to adapt the *MatchPad*. The interchangeable framework of the *MatchPad* (Figure 1) simply requires a new event dictionary and icon set for adaptation.

8. Conclusion

From the process of developing the *MatchPad* we concluded that glyph-based visualization offers an efficient and effective means for conveying a large amount of event records, especially in situations where users need to gain an overview of the data in order to make mission-critical decisions with very limited time. The metaphoric glyph design was the most appropriate for this particular application. This visual design minimizes the needs to learn and memorize the coding scheme associated with the glyphs. We introduced an effective layout algorithm that “combined with tablet interaction” provides fast intuitive navigation of the visualization. Since the attributes within the framework are interchangeable, this can be adapted for other sports and application areas.

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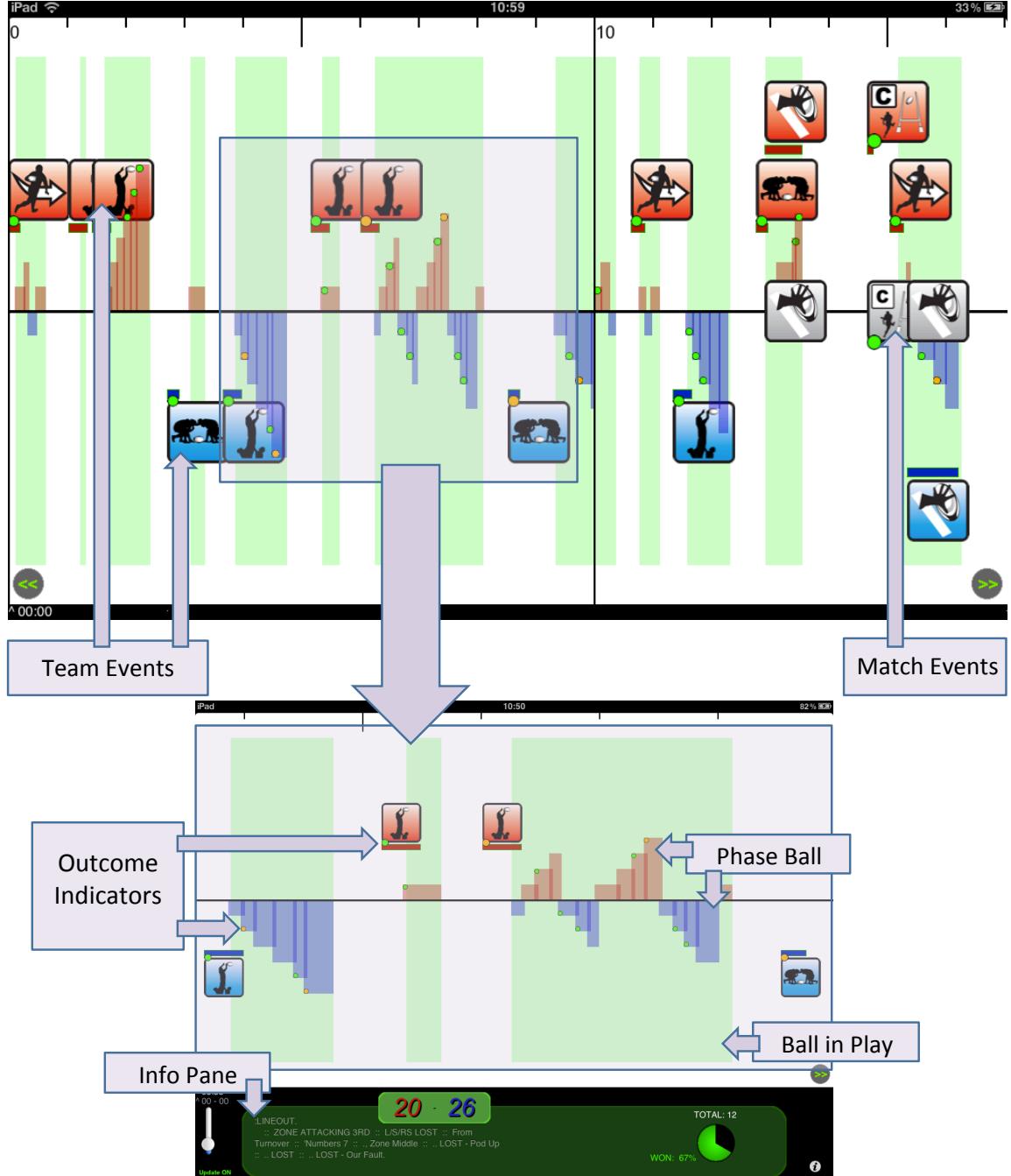


Figure 7: Screenshots of the MatchPad. **Top:** Overview of a 17 minutes period from a match using the MatchPad. Match and Team events are depicted using metaphoric pictograms that are instantly recognizable. Home team events are shown in red, above the centre line, and away team events are shown in blue below the centre line. The user can also choose whether to show critical match events such as scoring events and referee decisions on the centre line due to their high importance. **Bottom:** Zoomed-in view on a region of the visualization. Phase ball actions are shown using coloured regions sized dependent on duration and phase count. Outcome indicators for positive or negative results are shown using green and amber circles respectively when the information is available. Ball in Play events are shown by the pale green background on the timeline. The information pane at the bottom of the screen provides more in-depth detail for a particular event when selected by the user.

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