A Final Project Report on

FORVIZOR : VISUALIZING SPATIO-TEMPORAL TEAM FORMATIONS IN SOCCER

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ABSTRACT

Team formations is considered to be one of the most key factor in soccer as it helps players in plotting tactics, positions and jobs if individual players on field and also helps in assessing the performance of team overall. Now evaluating such formations is also considered to be important as it helps in understanding the team's or individual players play that helps in determining their strengths and weaknesses and can help in improving it further. So studying such Spatio-Temporal data like multivariate features, soccer formation analysis is quite a challenge right now. So in this paper, the authors carefully studied and collaborated with a group of domain experts in analyzing the team formations by designing goals from a set of requirements. And a result of which, ForVizor, a visual analytics tool was designed that helps in understanding about the formations, it's corresponding changes and also oversee the reasons of such changes. All these were implemented with the help of a couple of case studies.

1. INTRODUCTION

Soccer is one of the most popular sport in the world and also inculcated the interest of soccer-tactics. Where analysis is also considered to be one of the most important factor and with which various automatic tools were brought into picture to study and also collected related soccer data because there wasn't any proper study about this. And also the tactics can actually be studied in the form of team formations (Eg. 4-4-2), that depicts **four defenders, four midfielders and two forwards**. So with this one can actually know about factors like defense, strike strategies, coverage, etc. For example, Considering the great impact of formations, various other authors also proposed different methods to visualize the Spatio-Temporal formations as seen like Line charts, heatmap, etc. as shown in the figure 1.1 but didn't mention anything about spatial changes.

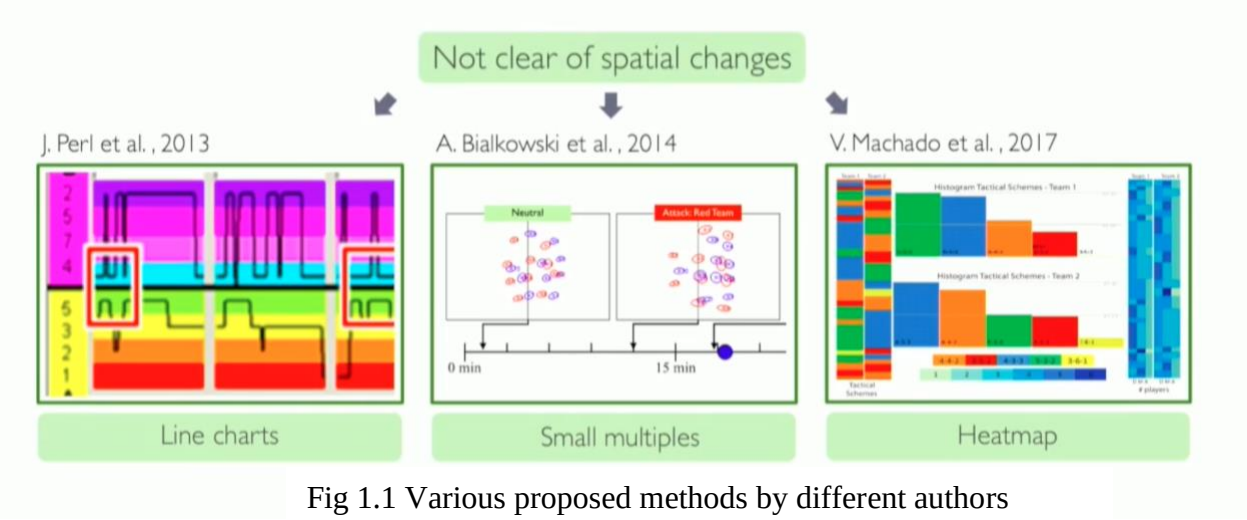

Fig 1.1 Various proposed methods by different authors

But all these focused on low level actions like – Player actions and key events (goal, pass, replacement, etc.) and didn't clearly show the spatial changes of formations. In soccer, for visualizations, several applications like soccer stories, bring into the pitch, and the pressure visualization were proposed to do a good job in analyzing the data as shown in the fig. 1.2. However, their techniques cannot fully address the problem of formation analysis, which has unique data characteristics and different design requirements. Therefore, a proper visualization system for formation analysis remains absent.

Fig 1.2 Various proposed methods by different authors for visualizations

In this study, authors designed **FORVIZOR** to fully analyze the Spatio-Temporal formations. Users can hover on a matrix to see the summarization of the two teams formations, jump to the formation floor to detect the spatial temporal changing patterns and zoom to see the detailed transitions and click to learn prayers movements information. Users can also flash on the timeline to get more detailed information. However, developing such a visualization system remains difficult due to three challenges. The first challenge is acquisition of reliable source of data. The tracking techniques are not robust enough in real applications, and may be influenced by the video resolution, one may lack of players, and different camera angles. The second challenge is the problem characterization of formation analysis. Although domain experts have long experience in analyzing formations, both of their work, concentrated on a specific target, thereby lacking a follow comprehension of the problem domain. The third challenge is the visualization of formation changes. According to experts, the visualization should be able to disclose the Spatio-Temporal nature, and be connected with multivariate soccer data for in depth analysis. So to address the primary challenge, an interactive labeling tools was designed unlike the automatic method, because this would help in knowing the errors effectively from the obtained raw soccer data. And for the second challenge, the authors worked with a group of experts for 10 months where they went through the domain problems and did a formation analysis on the basis of already existed

studies and obtained a feedback through meeting and discussions that happened every week as shown in the fig 1.3.

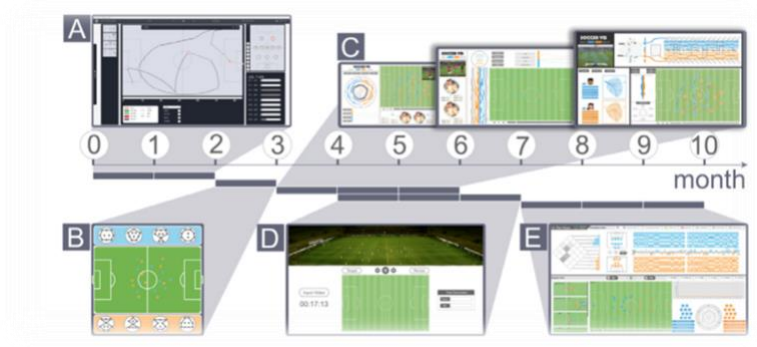

Fig 1.3 Main Stages of work. (A) Prototype System (B) Problem Characterization (C) Visual Design (D) Data Processing (E) System Implementation

Finally for the third challenge, authors designed a system ForVizor to fully analyze the formations. Users can hover on a matrix to see the summarization of the two teams formations, jump to the formation floor to detect the spatial temporal changing patterns and zoom to see the detailed transitions and click to learn prayers movements information. Users can also flash on the timeline to get more detailed information.

2. RELATED WORK

In this part of work, authors mainly reviewed about a couple of problems, which were, analysis of soccer and soccer visualization

ANALYSIS OF SOCCER AND SOCCER VISUALIZATION

Various methods and tools were introduced to analyze the game of soccer and its data like distance-based, region-based and trajectory based but they were useful in analyzing the data in various ways. And also author mentioned another couple of author's work that actually was based on team organization and other one was based on finding a soccer event that was based on player's and soccer ball position. And also a prominent work of Bialkowski et al. was mentioned in the paper by the authors who used a minimum entropy data partitioning method to find players positions, patterns and team's behavior. But as mentioned all these methods that were given didn't actually

focus on spatio temporal team formations. Various visualization tools were provided like table tennis, tennis, basketball, etc as mentioned in the paper. But as mentioned even these didn't try to study about how team formations play an important role in analyzing the game. So by keeping all these points in mind, all the experts worked closely by creating design goals to solve the issue of team analysis.

3. DATA PROCESSING

So as mentioned in the previous sections, the experts worked on data formation stepwise. The first step is to acquire raw soccer data to get player's data and the again plot to two dimensional pitch. At the beginning, they developed a prototype system to track their feedback, characterize the domain problems, iterative visual designs to process the soccer data. And finally, they implemented the visualization system. And that's how they started designing the system where, first is the data processing. Where they first created raw soccer videos and use tracking techniques to acquire players positions. Then map those players positions to the 2D pitch. And finally used the minimum entropy method to detect formations as of fig. 3.1. Now using minimum entropy method (This is the most conservative way of measuring the unpredictability of a set of outcomes. So that's the reason authors chose this method to detect formations. One may ask why not maximum? Because the maximum entropy best works to know about current state in system with largest entropy. So in this case, according to my knowledge this maybe used to study individual player's stats) to find out overall formation of teams and in turn the experts were asked to provide names/labels in-order to obtain formations.

Data Description

Now as a part of this, it's known that soccer will have two teams to play against each other and has eleven players in a team in which there will be positions based on 4 roles chiefly as goalkeeper, mid-fielder and forward. Now formation is something that tells us about players places on field

like considering 4-4-2 as mentioned in the introduction part. Several team positions are there in which each and everything can be considered for attack, defense, etc.

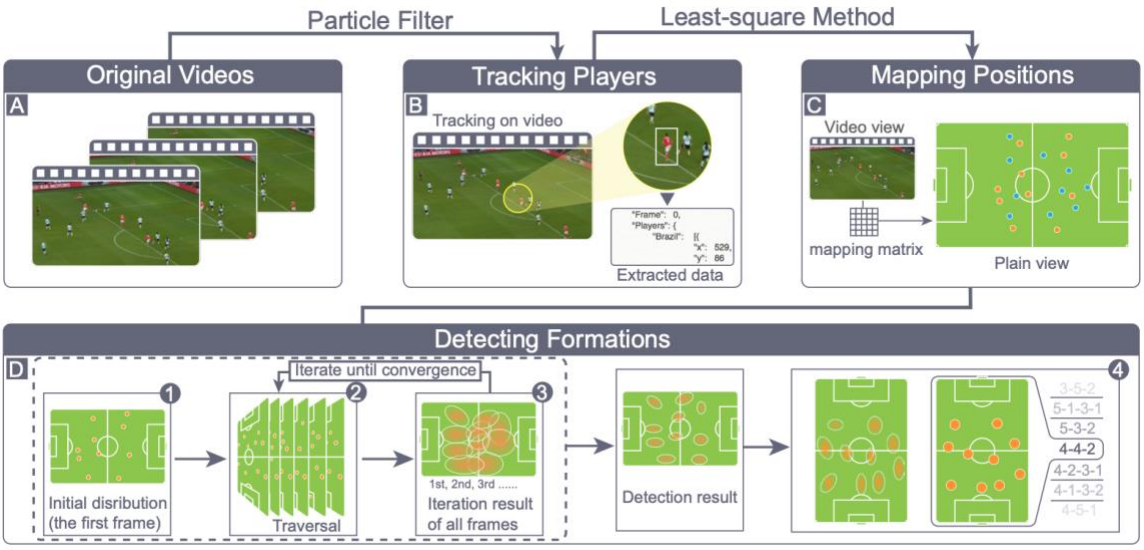

Fig 3.1 Pipeline of Data Processing. (A) Soccer Video Collection (B) Player position collection from frame-to-frame (C) Mapping positions to 2D layer in various frames (D) Formation detection from players position into steps: D1 initial role production for 10 players, D2 Assigning players to various roles in frame. D3 Iterating over D2 until player's positions come together D4 Finally labeling detection result to get final formations

Semi-automatic Tracking

Now authors have actually studied about few approaches like YOLO and CREST for detection and tracking respectively but none of them were able to talk about tracking. And also they detected few problems about automatic tracking, which were unpredictable behavior and Loss of players characteristics. In the former one, the main problem was when the players try to move in a fast moving manner, or either moving in an opposite way then the tool wouldn't track such movements and in the latter one the authors went through a system by the name Pixellot that helps in viewing the players on the field in a long shot but the problem was when players get overlapped or form together as a wall then tracking will be lost and wouldn't give accurate results. So to overcome this a semi automatic tracking was introduced in which, they made use of tracking using computer vision. One of the major advantage over automatic tool is that user can stop and fix the errors, the computation of bugs will be minimal and be efficient. Now the tracking will halt in 3 cases, The first is when the selected tracking moves from one place to another and the user can rewind back

and again make a correction. Secondly, it halts when the target gets blocked so there are chances when players come together during a game so the user can set such tracking by themselves. And finally it's when the result has less confidence probability. So if that is less than predefined threshold, the tracking will come to halt and users can manually rectify such points in this way a couple of users can obtain the game details.

POSITION MAPPING AND SMOOTHING

In this step, the result will be plotted to a two dimensional map to get the actual positions of the players and can also estimate using a 3*3 matrix. The main point here is that the players location is actually high-flown by the noise. So the authors used filtering in-order to smoothen the results.

FORMATION DETECTION

Formation detection is something that wasn't paid any attention since the beginning. So the experts and authors want to study and understand about team formations from the raw soccer videos but that's time consuming because it's a heavy process to collect raw data which would take high amount of time and information. So in-order to settle this the authors made use of Bialkowski et al. algorithms that's similar to constrained K-Means which was used in analyzing team formations by using it's respective segmentation and detection formations. Now the frames that didn't posses any soccer balls were eliminated after which a group of experts were invited to name the data which has been acquired so far.

4. BACKGROUND AND SYSTEM OVERVIEW

In this section, important aspects like requirement gathering, respective goal designs and also the overview of the system designed by the authors.

Requirement Analysis

For this, the authors associated with a group of experts that include Senior Sport analyst (SA), Top soccer coach in Asia (SC), professional soccer players (SP) and some PhD students from sports science department (PhD) for 10 months to develop visual analytic method to study team

formations, where each and every person from the above team have played several matches previously for years, did some research in analyzing soccer game by studying goals, passes etc that actually also helped in understanding in respective team's tactics right before scoring the goal. But they thought that this way of analyzing is tedious and takes much time than expected. So keeping these factors in mind, a broad visualization system was designed with a set of design goals by satisfying the requirements accordingly. Now as mentioned the experts studied the design overview for 10 months, as given.

Applying prototype system – 2 months – So based on SoccerStories a pre-existing system for visualization, experts made use of this in-order to boost the system's effectiveness. So overall they got what they expected about efficiency in terms of visualization.

Characterization of Domain Problems – 1 month – The main motto was to obtain the details of team formations from weekly meeting with the experts by summing up the details.

Iteration of System Design – 3 months – All the observations done so far were taken into account to further filter the requirements and enhance the system design by discussing these changes during every week's meet.

Soccer Data Processing – 3 months – This step was mainly based on hit and miss method for semi-automatic tool data gathering which was done by SPs and PhDs.

System Development – 3 months – So considering all above steps, methods, data, etc. a testing versions i.e alpha-beta versions were developed so each time they tried testing it accordingly by revisions and made the system better.

List of Requirements

There were totally six requirements –

R1 This focuses chiefly on how the play circumstances change from time to time like important events that helps in collecting overall important points.

R2 It helps in finding how frequently the formation pairs were formed and also the variations among them this would help them in understanding the game characteristics.

R3 This deals with how formations evolve and differ in every situation in either of the teams. Experts found that it tend to change as per the scene at that particular moment and also one team can change according to the opponent formation change. This helps in understanding the formations of either of the teams.

R4 This requirements helps in understanding the after result of changes of formation that would bring some notable variations like it may result in a successful goal or a ball miss after changing from one formation to another.

R5 The reason behind the changes in formation are studied in this requirement as it's kind of convoluted and it's also connected with factors like current players positions, goals, etc during the game. So all these factors will help in unfolding the decision process of formations.

R6 Finally, this requirement analyzes the players performance in a specific formation because there will be various players present in the game. So there is a need to understand the individual behavior of each player and it's reason to analyze if the formation would be an optimistic one or not.

Design Goals

Now after gathering the requirements required for the model, all of them were considered and a set of design goals were formed as –

G1 First, the narrative timeline visualization of games situations - As far as they're familiar with the timeline visualization, this method can provide them a visual summary of game situations.

G2 Spatio-temporal representation of formation changes, or in depth investigation. Experts look forward to an effective visual design to disclose the spatial temporal nature and to enable the visual tracking of different areas and different players.

G3 Visual connection of formation changes and multivariate information -- Experts needed to tie or integrate multivariate soccer information to evaluate the effect of, of a formation change or to explain the reason of that change.

G4 Comparative analysis of two teams formations – Experts require a comparative analysis to compare the frequency formation of the two teams. It can help them identify the different characteristics, and to explain the result of the game.

G5 Context preserving view of game statistics – Analysis of game statistics is essential for assessing the performance of teams and players. Therefore this can be used in understanding the coordination between game statistics and context information.

G6 Intuitive glyphs of soccer data – Experts want this to be designed to illustrate and visualize events, formations

SYSTEM OVERVIEW

In this study, authors designed **FORVIZOR** to fully analyze the spatio temporal formations. In which there are mainly two views, namely, Display view and Formation View. In which the former one depicts an overview of formation of teams and also the condition of game. And the latter one is a refined view in which users can look into the game in more detailed way with the help of statistical graphs as seen in the figure 4.1

5. VISUAL DESIGN

Keeping in mind about the system overview that was designed based on requirements and design goals, G1, G2 and G4 talks about formation changes and G4, G5 talks about detailing about formations information as seen in the figure 5.1. In addition various Intuitive glyphs were designed to represent the soccer data, and the actions to coordinate all components as of figure 5.3. So based on the design goals, the FORVIZOR system was designed. Blue encodes Team A and orange to encode Team B. So coming to a detailed way,

Users can hover on a confrontation matrix to see the summarization of the two teams formations, jump to the formation floor to detect the spatial temporal changing patterns and zoom to see

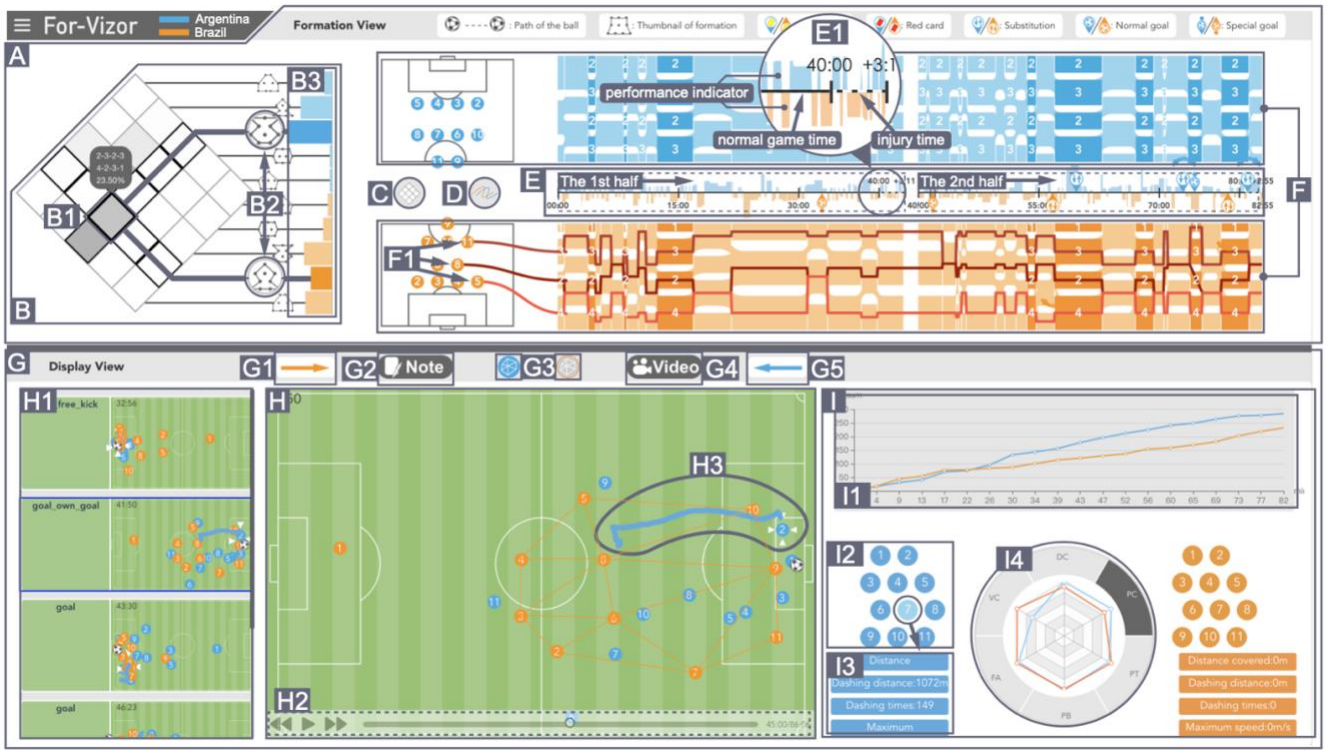

Fig 5.1 System Interface. Two views – Formation View (A) and Display View (G). Confrontation matrix lies in Formation view (B) and narrative timeline €, two formation flows (F), Pitch (H) and statistical dashboard (l)

the detailed transitions and click to learn prayers movements information. Users can also flash on the timeline to get more detailed information.

OVERVIEW OF FORMATION VIEW and DISPLAY VIEW

A clear formation view was provided to show the spatio-temporal changes. And a display view to provide the context information**. In the formation view**, we use a narrative timeline to present the game situations, which plays key events on a timeline, and a bar chart behind is used to show the defensive effect of formations. (the higher the worse) A confrontation matrix is used to show the summarization of the two teams formations

In a matrix, the row and column represent the formations of Team A and Team B respectively. And in the column, each matrix cell encodes the frequency of a formation pair in a match.

(the deeper the higher) The formation view is used to show the spatial temporal changing process of a team's formations. The formation flow and the confrontation matrix is also well coordinated, as we hover over the matrix respective flow can be seen in the formation flow. Now the formation flow in-detail. Is as follows, as of figure 5.2 At T1, they used 3 flows to represent the three spatial areas of the formation 4-4-2. The thickness of each flow is proportional to the number of players in the areas. Then at T2, We can see that player 9 moved backward to the midfield. So they used

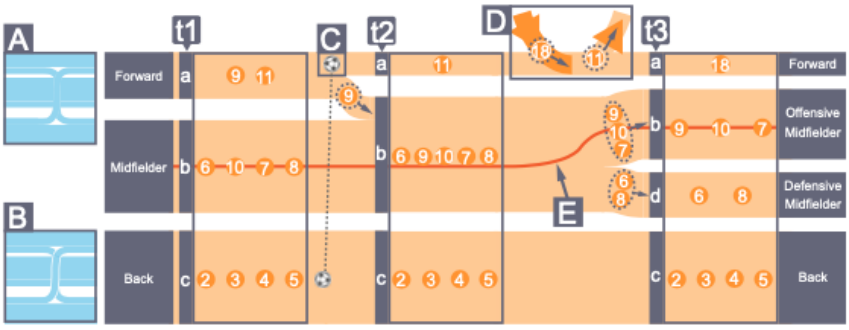

Fig 5.2 Formation Flow Depiction (A) Sub flows Overlapping (B) Appending white borders to a sub flow (C) Ball Possession Glyph (D) Glyph of Substitution

a split of the floor to encode this movement. Later at T3, the midfield further split into two flows, causing a formation change from 4-5-1 to 4-2-3-1.

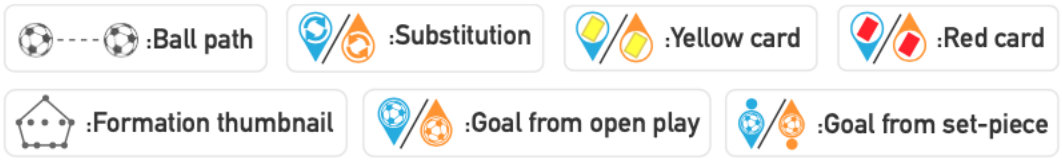

Fig 5.3 Intuitive Glyphs of event and formations.

So this setup can be useful in showing the players movements over time.

They designed plays to show the substitution behavior, the arrow pointing out from the flow means that our player in this flow is replaced by a new player. It also plays a ball in the flow to show the purpose or possession and connect the ball to show the percentage change. For the display view, the page records, players detailed spatial information where users can see the animation and watch the raw soccer video. Key events are recorded in the left. If these users can quickly jump to the

key events. A dashboard is placed in the right users can see different indicators of the two teams as well as players individual statistics. The dashboard and the page are also well coordinated.

And apart from this some alternative view was also designed in-order to depict spatio temporal changes as shown in Fig. 5.4 as a separated view and small multiples. In separated view users can view the overall performance in the form of line graphs studying about both the teams behavior and as shown in A2, a 2D graphical view of the pitch can be seen such that users can study the movements happened in the game and coming to small multiples it helps in understanding the formations of the teams as it shows an overall picture of the formations as shown in the fig. 5.4 and can understand if it was attacking, or defense.

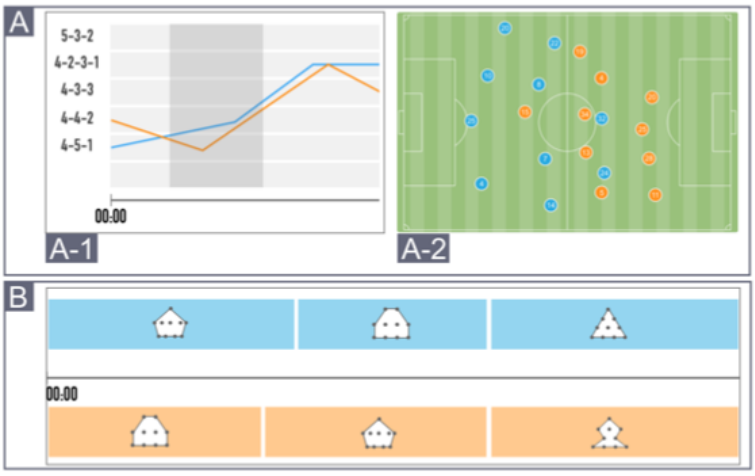

Fig 5.4 Spatio Temporal formation changes in the form of design Alternatives.
(A) Separated Views (B) Small Multiples

EVALUATION

Now for the evaluation purpose, domain experts were invited to do case studies. Experts include as mentioned before. A couple of case studies was introduced in the paper to demonstrate the usability of the system. So in this case, analyzation was done using two U-15 football championship hosted by CONMEBOL where the first one was between Argentina and Brazil and the second one was between Argentina and Peru.

MODEL EVALUATION – FIRST USE CASE : ARGENTINA's UNEXPECTED WIN

At the beginning, the timeline shows the outline of the game. Brazil scored two goals first, yet Argentina hit three goals in the second half and turned the tide. To analyze the game we turn to the confrontation matrix to obtain an overview of formations. As of figure 8, So three dark cells were noticed representing three formation pairs. Among them, formation 2-3-2-3 is an attacking formation featuring pass and control, formation 4-2-3-1 is employed to augment defense and formation 4-4-2 is for counter attack. Then we move to the statistical dashboard to understand the performance indicators. The radar chart shows that two teams have similar ball possession time, yet Argentina had more passes, showing pass-control style. Again by hovering over matrix cells and it can be found that Brazil employed 4-4-2 for defense and counter attack in the first half while they turned to formation 4-2-3-1 to focus on defense in the second half, especially that of midfield. The complete setup can be seen in the figure 5.5 below

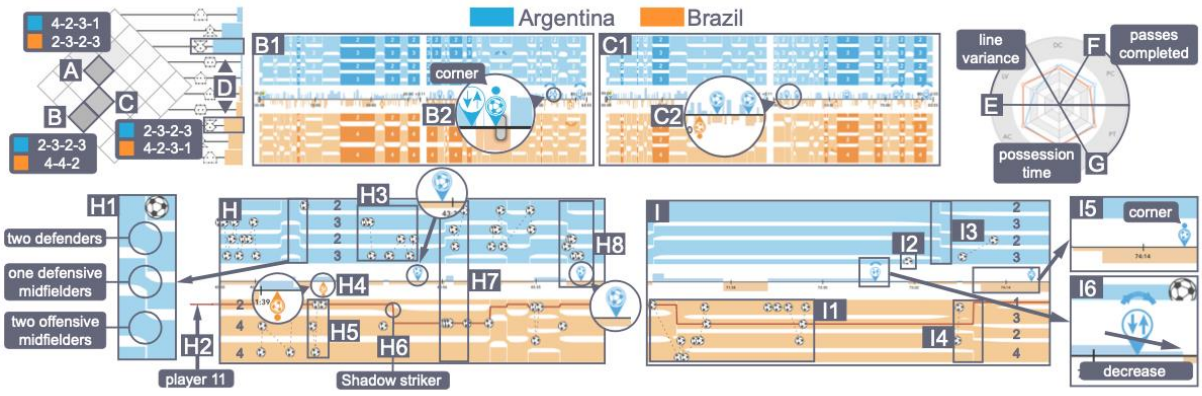

Fig 5.5 First Use Case Depiction. A, B, C and D depicts the confrontation matrix. Users can hover over B and C and corresponding confrontations are shown in B1 and C1 respectively. E F G depict the statistical indicators of Argentina and Brazil. H gives the formation changes details and game situation in the beginning of second half. Finally I shows the detailed information of last goal from Argentina

Argentina equalized the score at the beginning of the second half, which was the turning point of this game. So for further analysis, one can zoom and look for the details. In this period, Brazil mainly maintained 4-4-2 for counter-attack in-addition to moving a striker backward to change from 4-4-2 to 4-5-1 for increasing defense. By inspecting the player flows, they understood that the dropping striker was player 11, a shadow striker in formation 4-4-2 as seen in Fig. 5.5 Thereafter, the game situations are combined for further analysis. After continuous attacks from

Argentina, Brazil eventually regained the ball and passed the ball to a striker for a quick attack. (blue attacking formation and orange pass to the striker) At that moment, however Argentina failed to change to a defensive formation in time. Argentina's poor defense performance was also indicated in its high average area value. Moreover, they even hit an own goal. Despite that, Argentina persisted in attacking tactic, forcing Brazil to change from the formation 4-4-2 to 5-4-1 for a deep defense. Not this was actually considered to be a successful strategy such that they seized a chance to score a goal. Now in-order to verify the goal, the period of that particular goal was selected on the timeline and go to display view for more details. As seen in the diagram, one can see the video of the player's positions by playing that video in the display view by comparing it with the raw soccer video.

SECOND USE CASE – MASSIVE WIN

Just as the first case, the experts analyzed the second game between Argentina and Peru in which the games was analyzed in various views. In a way that the confrontation matrix two dark cells were noticed in which the formation of Argentina was 2-3-2-3 and Peru's was 4-2-3-1 and by continuing the process further it's noticed that there were repetitive attack forms from Argentina because of which their superiority was seen in the statistical graph as seen in the figure 4.6 Now to understand this in a more refined way, the authors viewed that the ball was in Argentina's control for quite a while before the goal through acute pass and control style besides Peru's defense. Now after Argentina's goal Peru immediately changed it's formation to 2-3-2-3 which is an attacking one with which even Argentina changed to 4-2-3-1 a defense one where Peru exceled in scoring a goal as seen in the figure 5.6. Now experts studied the formation fashion in a detailed way and found that ball was passed from player 11 to 6 in Peru team where Argentina's 3rd player try to

Fig 5.6 Second Use Case of the game between Argentina and Peru. A, B shows the confrontation matrix. Users hover over (A) and the users can hover over A and the matrix is shown in H. C depicts the statistical indicators in the entire game and D shows before the first goal. E, F and G shows statistical information of the second goal. The bottom most line gives the details of 5 goals in the game

nab the ball but couldn't achieve it as shown in the figure. Now by seeing the statistical view, it's found that the Argentina's formation wasn't effective enough to tackle Peru's goal. Then after, Argentina managed to score 3 goals again which lead them to a victory. Where the goal after first one was a penalty kick that was a part of attacking formation. Now the main problem here with Peru was defense which deeply failed in tackling with the ball.

FEEDBACK FROM EXPERTS

The experts were satisfied with the system and told that it's advantageous in the following ways - **The intuitive visualizations** of formation change the useful interactions for quality for coordinated views and videos, and the comprehensive functionalities for fulfilling requirements. Because it helped in understanding even an individual player's movements throughout in every level. Secondly, it was the system interplay where the prominence of display view was applauded and appreciated the coordination between the 2D pitch and raw soccer video that enabled the quick confirmation of analysis result. And finally, experts were satisfied with ForVizor regarding visualization that fulfilled the team formation requirements.

So on and overall, they also provided some suggestions for the improvement of the system, such as extending to analyze multiple matches, integrating more spatial information of formations like the left and the right side positions or players.

LIMITATIONS

Lack of video data : It's really difficult to get a high resolution raw video and analyze it. Because of which they were only able to do the process with two teams.

Secondly, it's the visual design of team formations, more of spatial information is to visualized in-order to make it more effective.

And finally, the performance of data processing procedure. Applying more advanced methods of visualization could enhance the data processing procedure.

6. CONCLUSION

Overall the study was considered to be the first attempt for analyzing formations by collaborating with experts. Main motive of the paper is to provide a visual analytic system called ForVizor to understand formation changes over-time and were able to create a design to visualize formation-changing patterns. They also enabled the visual tracking of the variation of spatial area and players for in-depth analysis. A unique design was created that helps in mapping the formations with a statistical indicators and then view it in the form of two dimensional video which was first in kind when it comes to a deeper analysis of team formations. Extending the work for experts to evaluate player's performance and teams tactics and also increase generalizability. The authors also mentioned that they will try not making this limited to soccer but making it available for American volleyball and hockey because team formations play a crucial role in those too.

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