Revealing the Invisible: Visual Analytics and Explanatory Storytelling for Advanced Team Sport Analysis

Manuel Stein[1], Thorsten Breitkreutz[1], Johannes Häußler[1], Daniel Seebacher[1], Christoph Niederberger[2], Tobias Schreck[3], Michael Grossniklaus[1], Daniel Keim[1], and Halldor Janetzko[4]

[1]*Department of Computer and Information Science, University of Konstanz, Germany*
[2]*VIZRT, Switzerland*
[3]*Institute for Computer Graphics and Knowledge Visualization, Graz University of Technology, Austria*
[4]*Department of Geography, University of Zurich, Switzerland*

***Abstract*—The analysis of invasive team sports often concentrates on cooperative and competitive aspects of collective movement behavior. A main goal is the identification and explanation of strategies, and eventually the development of new strategies. In visual sports analytics, a range of different visual-interactive analysis techniques have been proposed, e.g., based on visualization using for example trajectories, graphs, heatmaps, and animations. Identifying suitable visualizations for a specific situation is key to a successful analysis. Existing systems enable the interactive selection of different visualization facets to support the analysis process. However, an interactive selection of appropriate visualizations is a difficult, complex, and time-consuming task. In this paper, we propose a four-step analytics conceptual workflow for an automatic selection of appropriate views for key situations in soccer games. Our concept covers classification, specification, explanation, and alteration of match situations, effectively enabling the analysts to focus on important game situations and the determination of alternative moves. Combining abstract visualizations with real world video recordings by Immersive Visual Analytics and descriptive storylines, we support domain experts in understanding key situations. We demonstrate the usefulness of our proposed conceptual workflow via two proofs of concept and evaluate our system by comparing our results to manual video annotations by domain experts. Initial expert feedback shows that our proposed concept improves the understanding of competitive sports and leads to a more efficient data analysis.**

***Index Terms*—visual analytics, sport analytics, immersive analytics**

I. Introduction

To improve their performance and results, team sport clubs regularly employ interactive video analysis. The goal of a video analyst is to detect weaknesses of their own as well as opposing teams, enabling them to gain advantages in the competition. Findings are typically presented to the team members, coaches, managers, and other stakeholders in form of manually annotated video clips of previous matches. The annotation is performed with the help of various symbols such as colored arrows, lines or rectangles. Afterwards, the annotated match scenes are used in the team briefing. The resulting annotations, however, are not only interesting for video analysts. Television broadcasting companies are using manual added annotations to explain interesting moves to their audience as well as to reveal alternatives. State-of-the-art industrial solutions (for example Vizrt http://www.vizrt.com/products/viz_libero/) support journalists by providing methods to draw single symbols, to manually highlight players as well as to aggregate player movement by a density heat map.

Manual in-depth annotation and explanation of soccer matches, however, is not feasible because of high-frequent matches during seasons. An additional factor is the duration until suitable annotations must be provided. This affects, e.g., (sports-)TV broadcaster that aim to give first insights and reasonable stories already after a short commercial break. There is a natural trade-off between invested resources (e.g., time, persons, other resources) and quality of the analysis. Recent developments in visual analytics for team sports aim to support the effective analysis of sports, including soccer. Automatic player and ball tracking (and directly derived data such as speed and acceleration) has recently become widely available in major soccer leagues as an additional source of important information for analysis. However, this additional data is mainly used for quantitative comparisons. Qualitative analyses as the automatic selection and combination of visual analysis techniques which are helpful to identify and understand patterns of movement and player performance is a challenging problem. On the one hand, human analysts are able to intuitively highlight interesting aspects by selecting the proper tool in their toolbox (status quo) but are limited with respect to time and possibly, also cognitive biases. On the other hand, automatic annotation algorithms have a set of visualization algorithms but lack the human ability of assessing when to choose and how to combine visual annotations as illustrated in Figure 1. The inherent combinatorial problem leads to an exponential search space not feasible for interactive inspection.

We contribute a conceptual workflow for finding a valid and useful solution to identify suitable visualizations in this large search space. Our approach includes a rating-based approach for the semi-automatic selection of visualizations and creation of match reports. Our concept includes four consecutive steps: The **classification** of a given situation rating and verifying whether a certain visualization is interesting or not as a first step, followed by a **specification** to take the context as well as

978-1-5386-9194-6/18/$31.00 ©2018 IEEE

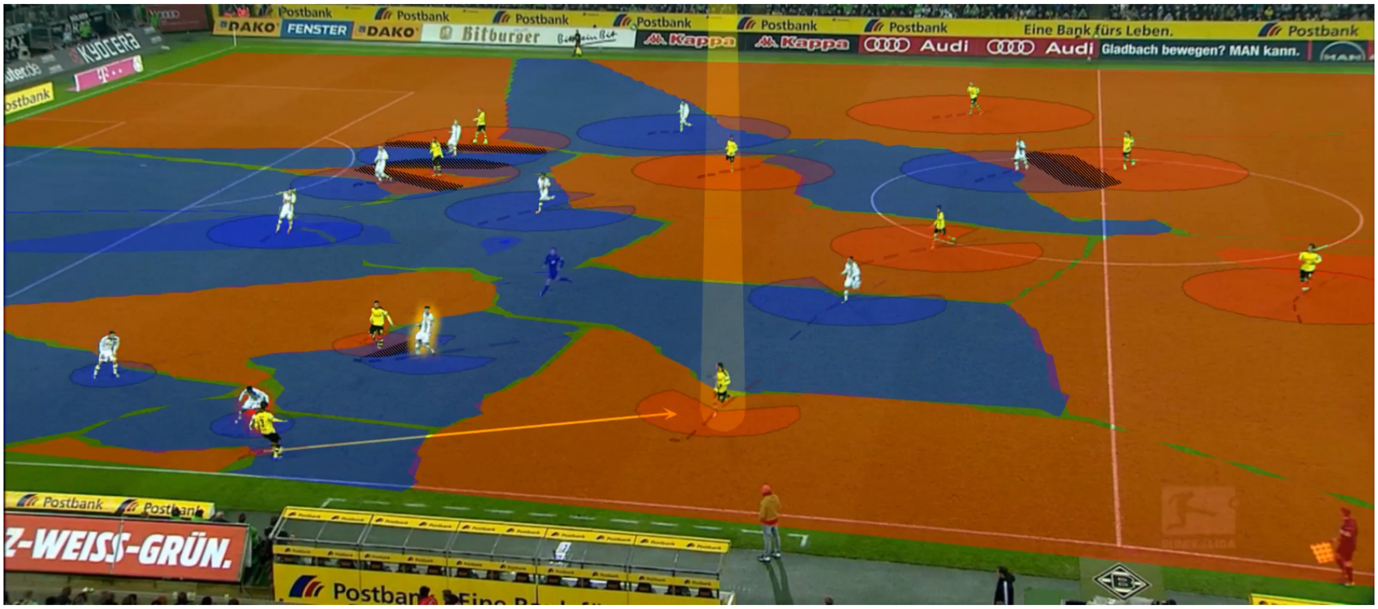


Fig. 1: Various visualizations have been proposed for the analysis of team sports. It is, however, often not clear when to choose and how to combine visualizations. The figure illustrates techniques for interaction spaces, free spaces, pass alternatives and dominant regions [1], [2].

the characteristics of a situation into account. Using the results of classification and specification, user specified selections of visualizations can **explain** a given situation. Our conceptual workflow concludes by the assessment of **alterations** that would have been possible during a respective match scene. We propose to employ our concept in the original input video recordings via Immersive Visual Analytics in order to improve intuitive understanding. This will extend the analytical possibilities, e.g., during television coverage of team sport events by providing novel ways to extract and present interesting stories with the help of visual analytics. We give several showcases in the soccer domain, focusing on player interactions, player behavior as well as match events. Additionally, we provide initial expert feedback to our proposed approach.

II. Related Work

We briefly discuss work related to visual analysis of movement data in general and to sports data in particular, before delineating our work from the state of the art.

A. Interactive Visual Analysis of Movement Data

Movement data arises in many application domains, and many works address interactive visual analysis of movement data. Specifically, works have addressed visual analysis of movement of single entities or groups of entities. Movement can basically be described in space-time as trajectories, and techniques have been proposed considering the visual abstraction of large trajectory data for, e.g., cars [3], vessels [4] or other traffic entities. In addition, multivariate annotations of movement measures such as acceleration, environmental factors etc. can arise and prompt the problem of appropriate integration into the visualization. For an overview of techniques and problems in visual analysis of movement data, we refer to the recent textbook by Andrienko et al. [5].

For large sets of trajectories, visualization per se may reach scalability limits, leading to overplotting and cluttered displays. Furthermore, it may be difficult for users to find relevant movement patterns in large data sets as sequential visual inspection is not efficiently feasible. To this end, several data analysis techniques can be helpful. For example, detection of potentially relevant trajectory segments can be attempted by analyzing the temporal behavior of certain movement features to identify outliers or recurring developments [6]. Data reduction by clustering can provide overviews over large amounts of trajectory data, leading to groups of trajectories that can be compared and related [7].

B. Visual Analysis of Sports and Soccer

The topic of visual analysis of invasive team sports data has recently attracted much research attention [8]. There are many works to visualize sports features. One class of methods focuses on visualizing match features like events or scores with only two examples being tennis scores [9] or table tennis scores [10]. Another class of techniques considers especially movement-oriented features in sport matches, with soccer being a prominent application due to research and public interest. The *SoccerStories* [11] system supports soccer match analysis by an overview and detail interface of individual game phases. For each game phase the main actions of the phase are identified, e.g., a cross, a long run or a shot. Tailored visualizations are provided for each of these main actions, which are displayed on a stylized soccer pitch, and actions are aggregated into a series of faceted views to show the game phases. A phase is an interval in which one team is in possession of the ball, and the phase ends when the ball is lost to the other team. This notion allows the segmentation of a soccer match as the basis for its interactive exploration. However, no automatic segmentation is provided, and the interactions of contacts by different teams need to be manually found.

The automatic segmentation of sequences of a soccer match by means of clustering was considered in previous work by Janetzko et al. [12]. A number of trajectory features such as acceleration, turns, or speed of movement was used to describe sequences in a sliding window approach, and based on this description a clustering of game intervals was applied. The introduced approach allows to explore a match by selecting clusters of such game situations, by different visual views including a timeline, soccer pitch and feature representations using Parallel Coordinates. The representation of game situations using features allows the application of automatic classification methods to detect relevant game scenes, which is particularly useful when the manual sequential exploration of games is not possible, i.e., when analyzing and comparing large amounts of game data such as a whole season of matches.

Semantic events in soccer games can be detected by various techniques. One approach is to have an expert-defined set of rules which specify an event in terms of spatio-temporal constraints. For example, Tovinkere and Qian proposed a method [13], where a set of rules was defined to detect basic elements like kick-off and ball deflection, and from these compose compound events like shot on goal. Furthermore, Stein et al. classified game situations based on a selected set of game features [14]. An initial experiment conducted on a ground truth data set showed that potentially interesting scenes can be retrieved using the classifier, delivering a step toward user guidance in detecting interesting situations in large data. Perin et al. [11] also identified that several visualizations should be combined and that the primary object of observation and analysis in soccer is the pitch in order to support the complex soccer analysis tasks. The integration of soccer visualizations directly into a soccer pitch was done by Stein et al. [1]. By following this approach and directly applying our visualization to the pitch we keep the context information of the soccer game, such as the position of other soccer players, while still providing the analyst with additional information. Additionally, we provide interaction, not only with the resulting visualization, but also with the underlying data, in our case soccer players. By dragging and dropping individual players to different positions, we allow the analyst to investigate *what-if* scenarios, e.g., would this free space exist, if one player had a different position, which is an important part of the work of soccer analysts, which they need investigate and present to the trainers, players, etc.

C. Storytelling

Recently, the use of visualization to create a narrative context has been studied and several types of storytelling have been categorized. Lee et al. [15] describe the structure of a story as a sequence of visualizations where each visualization describes a specific characteristic of the overall story. One of the resulting challenges is to identify appropriate visualizations for given characteristics as well as to determine their order of appearance. Our semi-automatic annotation system creates stories in the form of annotated video recordings. Following the categorization of Segel and Heer [16] our generated story elements are a combination of the types *annotated chart* and *video animation*, in which we blend video footage with elements from trajectory and area-based visualization.

D. Summary and Delineation

Previous work in visual soccer analysis often relies on trajectory-based representations, and techniques to visually represent, cluster, classify or segment interesting game events (or sequences). In this work, we contribute to the classification of interesting scenes in soccer matches for exploration of potentially large soccer match data. A main novel aspect of our work is the concept of selecting appropriate visual representations and explanations of interesting scenes. Our overall workflow can be combined with existing approaches and is largely orthogonal to existing work.

III. Explanatory Storytelling in Soccer

Our concept for the semi automatic-annotation of match scenes is depicted in Figure 2. In this concept, we tackle the large search space by assessing the predefined, parameterized visualizations and, consequently, support the creation of a narrative of events in a soccer match. When applied, we envision our concept as particularly suited for summative preservation of key events of a match, e.g., in a TV sports broadcast. We structure our conceptual workflow according to the following very general questions for a given situation. Please note that these questions are very common in the visualization domain and are by no means restricted to soccer.

A. **Is the visualization relevant?** With this question we cover the transformation from data to visualization.
B. **What were the specifics of the situation?** We slightly adjust parameters of the visualization reflecting the situation context best.
C. **How did the situation evolve?** We bridge the gap between visualization and human with visual explanations.
D. **What are alternative situations or movements?** The iterative loop combining human and computational power with Visual Analytics enables to derive new insights.

A. Classification - Assess Available Visualizations

The first step of our proposed conceptual workflow is the **classification**. During the classification, each available visualization needs to be assessed based on the respective relevance for the given situation as well as on the task and analyst's preference. For example, the visualized free space of a goalkeeper might not be of large relevance during an offensive counter attack. Consequently, we need to identify

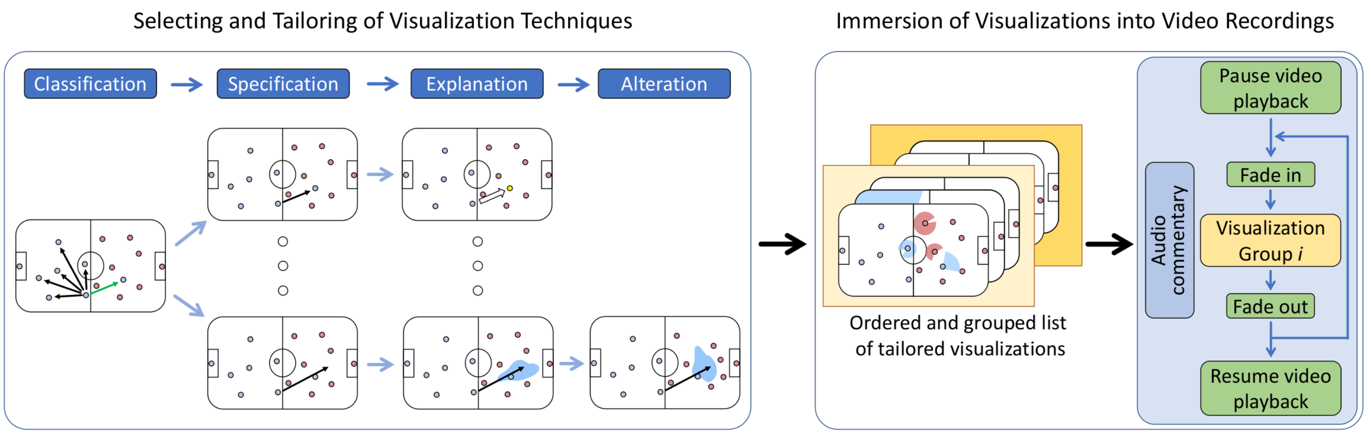


Fig. 2: Enriching a single situation: Our proposed process consists of two steps. Selecting and tailoring of visualizations and combining these visualizations with the video recording. The situation of interest is first classified and afterwards contextualized in the specification step. Fine-tuning visualization parameters helps to explain the situation further. An optional alteration step should allow *what-if* explorations. The resulting list of visualizations is the input for the combination of video recordings and visualizations.

and classify observed movement patterns and determine the suitability of the available visualizations. In order for our proposed concept to be generalizable, the classification will assess different features depending on the respective visualization. Still, some visualizations might be useful in all situations within a specific game phase (e.g., defending phase). These game-dependent meta-features will influence the classification of game situations as well.

B. Specification - Enrich with Situation Context

If the result of the classification (the assessment) matches a certain threshold, the conceptual workflow continues with the **specification**. The goal of the specification is to use the situation context to categorize and set up a visualization. A pass, for example, can be displayed in several ways focusing on different aspects like pressure, safety, or free spaces. Another game-specific meta-feature employed for differentiation could be whether it is a pass in the own or in the opposing half of the pitch. Features reflecting collective movement patterns are used as well for differentiation. In the case of passes, these features could be for example whether the pass is directed at a player or into his or her free space.

C. Explanation - Tell the Story

Once the observed situation has been enriched with context information, the existing fine-tuned visualization techniques can be used for the **explanation** of the movement. The results of the previous specification step are very important here as the added context enables to reflect different semantically meaningful situations. Depending on the context, different visual representations will be more suitable than others. In order to enrich the story presentation explaining the details behind a situation, we propose to automatically generate textual as well as audio descriptions. These descriptions assist the user with following the identified storyline. They ensure that the system and the user have the same contextual basis such that misinterpretations can be minimized. We intentionally propose to convey the explanation via the audible information transmission channel. On the one hand, this enables a clear distinction between following a game situation (audio commentary) and the scope for analytical reasoning (visualization). Associating the audio commentary with the well-known metaphor of a soccer commentator substantiates this distinction. Thus, users are able to focus on the audible explanation of the game situation or the visual details according to their needs. On the other hand, the audio description increases the effectiveness of conveying the story without the usage of additional screen space.

D. Alteration - What-If Analysis

A location change can happen for various reasons. A coach, for example, might want to predict possible changes or alternatives for the current situation as well as where a player should have positioned itself to prevent following actions. The **alteration** step, consequently, enables focusing on these *what-if* scenarios. As the implications of such location changes needs to be analyzable, each visualization needs to get recalculated during position changes so that experts are enabled to compare, confirm, or reject their hypotheses with respect to the displayed visualizations.

Further investigating what-if scenarios, however, is very complex, as each change might have unforeseen implications. Simply moving players closer to the ball will ultimately result in a potentially worse situation as, for example, more free spaces can open up. Furthermore, a player should theoretically be able to reach the proposed position respecting physics. We consider this as an optimization problem assuming that players are constantly trying to reach their optimum location with respect to all other player positions and respective goals. In order to detect possible alternatives, we need to define whether players are losing their optimum location and identify when they are moving less than optimal. Accordingly, one option could be to visually annotate where these players should have moved instead and why they should have moved there.

E. Immersion - Improve Intuitive Understanding

After the four-step concept selecting and tailoring visualizations, we need to create the **immersion** of abstract visualizations and video recordings. A special challenge in the creation process is to display the information at the right time for the proper amount of time. In order to allow the analyst to focus on the provided visualizations, we propose to stop the current situation and fade in the visualizations right after another (right part of Figure 2). This helps to steer the attention towards the annotation as well as prevents a cognitive overload and change blindness. A visualization itself should be shown as long as the provided audio commentator is speaking. Afterwards, the video continues to the next relevant scene.

IV. Proof of Concept

In order to showcase the usefulness of our proposed workflow covering the complete range of match analysis tasks, we provide a proof of concept in collaboration with several domain experts. The first domain expert has been an active soccer player and accredited referee for more than 20 years. The second expert has been an active soccer player for 15 years. Furthermore, he has been working as coach in the youth sector. In addition, he is currently studying sport sciences analyzing the annotation of tactical movement behavior in soccer matches. The third expert is playing soccer actively for more than 25 years and has been working as a coach for 12 years. Until recently, he has been working for the German soccer club FC Bayern München in the youth department. The fourth expert has been an active soccer player for more than 30 years and is now working as a coach. As certified coaches, they are very familiar with team briefings based on annotated video recordings. All invited experts are well aware of the structural requirements of video analysis and annotation, for example, from their participation in innumerable team briefings. Accordingly, we consider their input as highly valuable for a proof of concept of our conceptual workflow. We explained our proposed concept during several interviews and asked the invited domain experts to use our concept for the creation of automatic annotation workflows for passes (see Section IV-A) and passes into free spaces (see Section IV-B). For the proof of concept, we used a television match recording from the German Bundesliga being broadcasted on the Sky Sport TV channel operated by Sky UK Telecommunications [17]. All figures are extracted from this match and visually enhanced by our conceptual workflow presented above.

As a prerequisite for each presented proof of concept, the analyst has the possibility to provide an interesting video sequence serving as input for the story creation. We intentionally allow to make an initial manual selection in order to limit the created video annotations to what is interesting for the user. Nevertheless, previously proposed systems [14] can be used to automatically detect interesting situations for visual annotation. In order for the visualizations to be superimposed on the original video recording, we make use of the previously presented technology of Stein et al. [1]. The audio commentary is realized by making use of Microsoft's *Text-To-Speech API* [18]. A set of predefined textual comments is provided by the system and can be extended by domain experts anytime during their analysis. Depending on the classification and specification steps, the most suitable comments are chosen for the identified characteristics. Additionally, they are enriched with situation- and game-specific information, such as player names, directions of movement and locations on the pitch.

A. Passes

Passes are among the most important means in a soccer match to play around opposing players as well as to gain space. We apply our proposed concept in collaboration with the invited expert focusing on low passes. The resulting annotation workflow that can be applied automatically to any given input video sequence can be seen in Figure 3. The first step in our conceptual workflow (**classification**) is to define when a pass or a pass alternative is relevant for the understanding of a situation. For this purpose, the experts want that each possible pass is assessed by defined and established criteria [2] (e.g., pass distance, intersection interaction spaces, or pressure). If the rating of a pass exceeds a user-defined threshold, we will consider the pass or the pass alternative as relevant for the given situation. For the **specification**, we need to define in which variants a pass can be played. Our experts mostly differentiated between passes in the own and the opposing half of the pitch. According to our experts it can be assumed that passes in the own half of the pitch, e.g., back passes to team members, are safer since the probability to lose the ball is lower while passes in the opposing half of the pitch are considered more dangerous as usually more opposing players will try to interrupt it.

In the **explanation** step, we specify the visual representation of the respective pass variants. Our invited experts decided that passes in the own half are sufficiently indicated by arrows on the pitch. Additional visualizations are not required as the probability of a turnover is considered to be low. However, a pass in the opposing half of the pitch can be intercepted more easily by near opposing players. Consequently, the experts verify whether a pass can be intercepted computing and visualizing the corresponding interaction spaces [2] of nearby opposing players. Interaction spaces enable investigating which region a player is able to control with respect to their speed, heading, and distance to the ball. Another desired information is the pressure a player is experiencing as this increases the probability of losing the ball. Various models to calculate player pressure have been introduced in the past, e.g., by Andrienko et al. [19]. We visualize player pressure by a colored halo surrounding the pressing player using a color scale from yellow (medium pressure) to red (high pressure). Additionally, the invited domain experts decided that they want to highlight involved players such as pass receivers by a

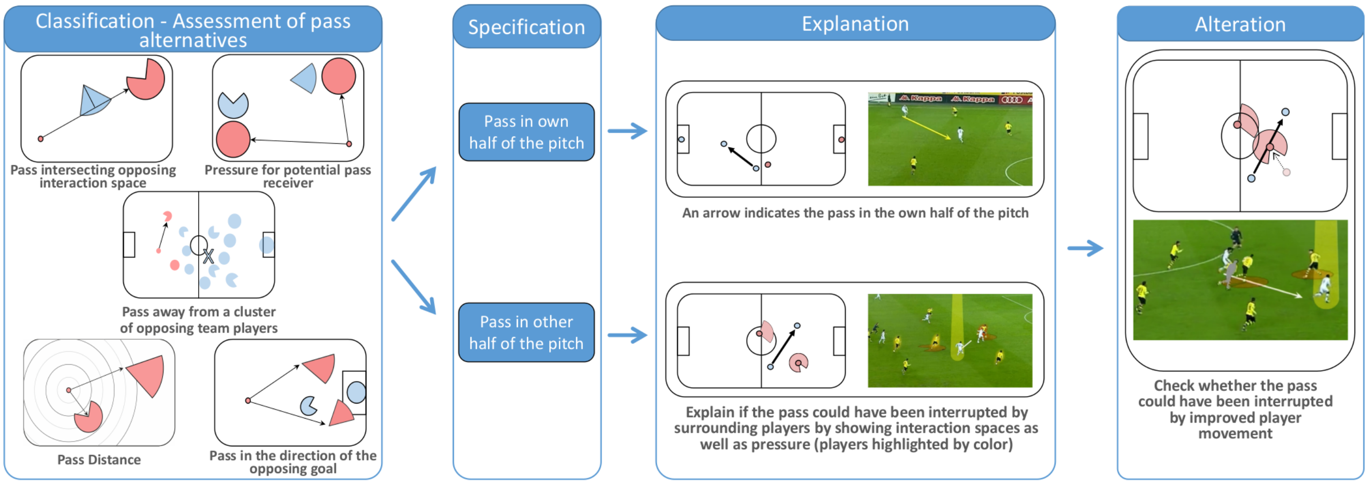


Fig. 3: Exemplified simplification by a common match situation. In this user-defined scenario, we automatically analyze [2] and visually annotate passes, depending whether they have been played in the own or in the opposing half of the pitch. During the explanation, we focus on contextual aspects such as whether a pass could have been interrupted through opposing players interaction spaces. Eventually, we verify whether the player movement could have been better.

spotlight visualization. In the last phase (**alteration**) of our applied conceptual workflow, the experts want to find out whether the pass could have been intercepted by improved player movement. Accordingly, we automatically detect close players which would have been able to gain possession of the ball if they altered their movement slightly based on their corresponding interaction spaces. Those players can be automatically moved to their new position.

B. Passes into Free Spaces

A special, more complex form of passing is the pass into free spaces. Here, it is crucial to analyze the observed cooperative and competitive group movement resulting in the spaces players are able to control. The resulting annotation workflow created in collaboration with the invited experts can be seen in Figure 4. During the **classification** step, our experts defined two main requirements for the creation of a story. The first requirement focuses on the free space of the players, defined as the space a player is able to reach before any opposing player. Several criteria have been proposed in previous works [2] to assess how good and relevant a free space is in terms of offensiveness. These criteria cover the size of the respective free space, its distance to the opposing goal, as well as how much opposing players can be outplayed. A positively evaluated free space without a realistic chance of passing the ball to this position is not beneficial for the analysis. Consequently, the experts add as the second requirement whether the ball could be played into the identified free spaces. We check if a ball can be played to a certain proposed free space by assessing the possibility to play a pass from the player who is in possession of the ball towards the center of the proposed free space. The pass assessment is done based on our defined criteria from the first proof of concept containing regular passing behavior. As we assess the risk of losing the ball, the result is a relevant free space with a high change of not losing the ball possession.

The **specification** and visual **explanation** is focused mainly on the movement behavior of the involved players. The experts distinguish between two main types of possible match situations: The first case describes situations in which no opposing player is limiting the player's path to the opposing goal using a respective free space. In this case, the movement of players of the own team is important, according to our experts. The experts want to find out whether players are able to detect and use their own free spaces. Consequently, we visualize the free space as well as the possible pass options and whether the movement of a player follows the created free space in the next few seconds. The second kind of situations occurs when opposing players strongly influence the arising free spaces, forcing the player who is in possession of the ball to react to their exact movement. To cope with this specific situations, we need to analyze how free spaces are influencing and limiting each other. Consequently, we calculate and visualize the intersection of each free space with every free space of the opposing team for a user-defined timespan, e.g., the next two seconds. This allows detecting which and how opposing players are reacting on a player's free space. Additionally, we visualize the future movement of nearby opposing players, giving us the advantage to verify whether opposing players detected and moved towards a dangerous free space.

In the **alteration** step, the domain experts are interested in detecting possible pass alternatives into relevant free spaces that have not been realized during a match. Therefore, we calculate at each timestep whether big offensive free spaces arise for the attacking team and assess the chances of a successful pass based on the criteria described above. If such a pass alternative in an open free space gets detected, we highlight the identified players automatically with a spotlight.

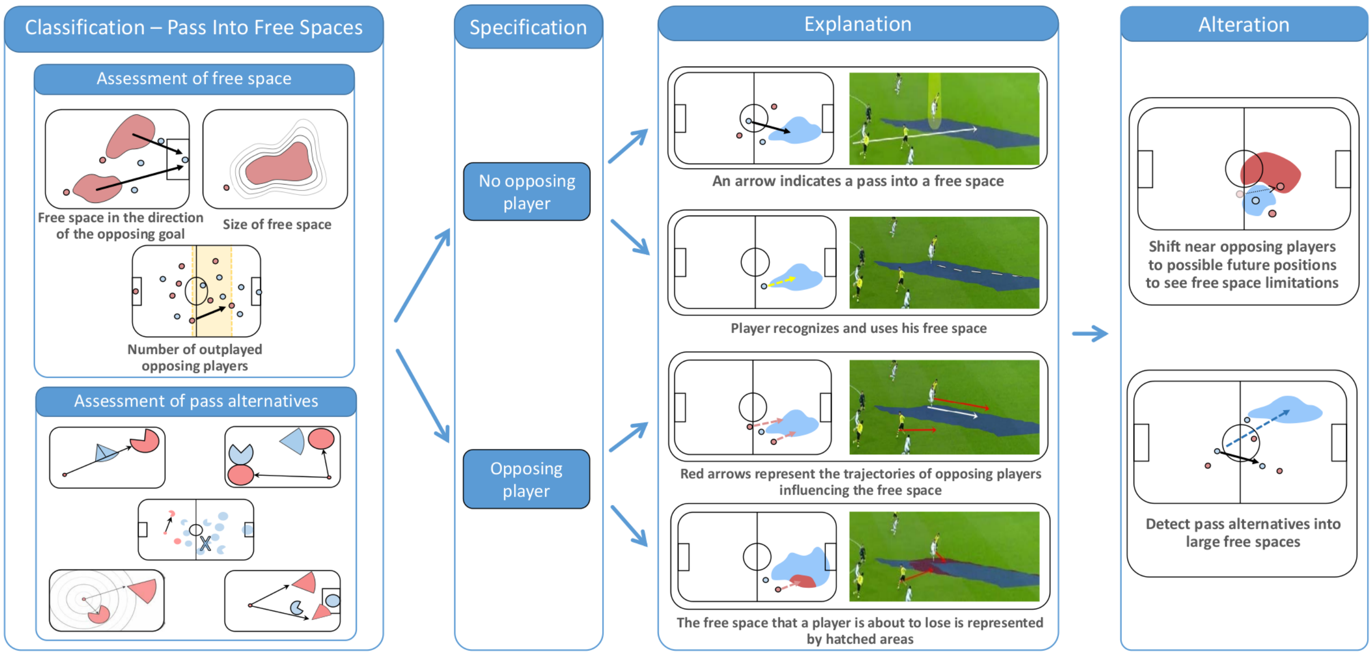


Fig. 4: Interesting passes into free spaces are annotated by incorporating cooperative and competitive group movement context aspects. We distinguish between situations where no opposing player is directly influencing an arising free space and situations where opposing players have a strong influence. The alteration step enables experts to be aware of not realized pass alternatives.

V. Initial Expert Feedback

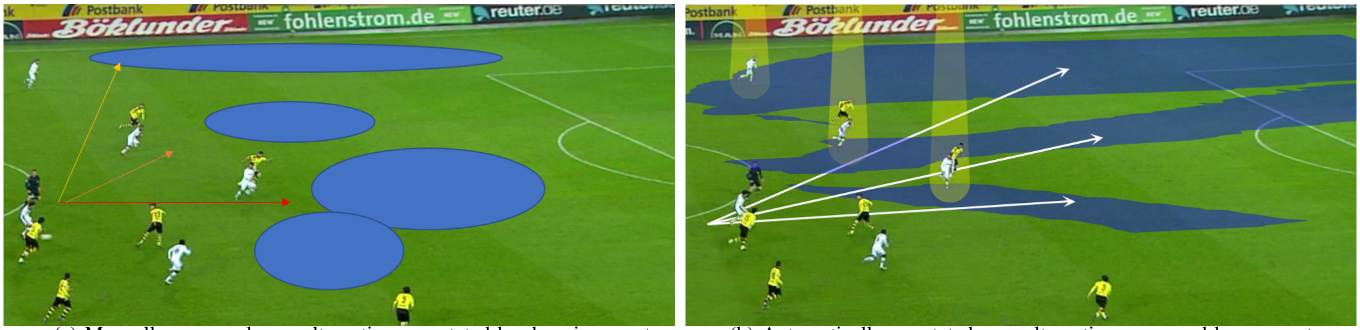
In order to validate whether our invited domain experts agree with the automatic created annotations of our proof of concept, we performed several experiments with each expert. At the beginning of a study, unmodified video recordings of match segments with a time span of approximately 20 seconds are shown to each expert. Afterwards, each expert is asked to replay the scene and to pause the recording whenever he wants to annotate something on the pitch. Experts can interactively draw on the pitch, using various symbols to highlight players and regions. After the entire situation has been annotated manually, we provide the expert with the automated annotation of the given video sequence. Together with our experts, we then compared and discussed the final annotations with and without automated support to identify strengths and weaknesses of our proposed concept. At every step, we encouraged the domain experts to express thoughts and *ad hoc* comments via the thinking aloud method [20]. Additionally, we recorded their interactions for subsequent analysis. Furthermore, we were particularly interested whether our proposed video annotations strengthen the trust of experts into their analysis.

The initial expert feedback revealed that all experts consider our concept as highly valuable for the annotation of soccer matches as well as other invasive team sports. The provided proof of concept is, according to our experts, illustrating the usefulness of our approach. For example, our implemented conceptual workflow for passes into free spaces is already perceived very similar to the annotation our experts would manually propose, as can be seen in Figure 5. Figure 5 (a) shows the manually added expert annotations while Figure 5 (b) shows the annotations proposed by our system.

The invited experts state that our proposed conceptual workflow is helping in filtering out probably unnecessary visualizations while still allowing the user to intervene in the analysis process when desired. This allows focusing on the important aspects of a situation. The single steps of our conceptual workflow are considered believable as well. The specification step was especially mentioned by one expert enabling to express, detect and visualize the different characteristics of a situation. The shown specifications of our pass proof of concept already reflect "*up to 90 percent of all possible cases*" (quoting one expert). Consequently, we believe our concept can serve as solid foundation for the creation of match annotations.

The experts also found the possibility to let the system annotate alternatives moves very useful while the user can still interact and decide whether he wants an annotation in the final story. One expert argued that he would have felt overwhelmed if he could not decide on his own which alternatives to show. Another expert suggested adding new workflows based on our concept for the analysis of the defensive behavior of a team, for example, the performance of the back-four-formation. Currently, most of our shown visualizations describe the offensive behavior of a team.

The way annotations are displayed in our system is also seen positively. The experts liked that involved players are highlighted within the original video recordings, e.g., by a colored halo or a spotlight. Furthermore, they approved our way of displaying the visualizations one after another and ex-



(a) Manually proposed pass alternatives annotated by domain expert

(b) Automatically annotated pass alternatives proposed by our system

Fig. 5: To validate the annotations proposed by our system, we asked domain experts to interactively annotate their findings on the pitch. Blue areas depict free spaces, arrows depict potential pass options while players highlighted with a spotlight indicate potentially involved players. The high similarity of both annotations suggests our concept is capable of supporting domain experts revealing invisible movement explanations.

actly synchronized when the audio commentator is explaining what can be seen. According to our experts, this allows to explain a complete situation in one playback. To this end, our invited experts praised the possibility to dynamically add visualizations to players and regions using a simple drop-down menu and by right-clicking on the respective object.

VI. Discussion and Extension Possibilities

We introduced a workflow concept for the semi-automated analysis of soccer game phases. Based on discussions with invited domain experts, we integrated a number of methods to detect relevant soccer event types and determine corresponding visualizations that can represent these by overlaying visualization on the video. The detection of situations and types of situations is a difficult problem, as it has to deal with segmentation in time and space. Main problems for a realized system include the *completeness* of the detections, and the *precision* of the detection. In our proof of concept, we have implemented a limited number of detection methods which however represent a set of important, frequently occurring events in soccer matches. While our set can be extended, it is a starting point and at this time suffices to demonstrate the principal functionality of our conceptual workflow. Obvious future work includes the extension of scene detection methods, and more evaluation on the precision of the detection. Eventually, if enough training data is available, Machine Learning methods could be applied to automatically segment and classify match scenes. Also given enough training data, classifiers can be improved that determine appropriate visualization types for scenes, given training data of user ratings on the relevance of views for situations. Such training data and benchmark data to evaluate the precision of the detection would be highly desirable. Possibly, a crowd-based experiment could be performed to obtain more training data to work with.

Since the alteration is a complex optimization problem, we plan in future work to put a special focus on ensuring that a proposed alteration cannot end in a generally worse situation. Currently, for example, moving one player to her or his locally improved position may result in even more arising free spaces for the opposing team on the global scale. To prevent this, we need to incorporate the movement of each moving individual on the pitch into the assessment.

Gathered initial expert feedback showed that experts were convinced by the applicability and effectiveness of our conceptual workflow. Our presented concept is seen applicable to other team sports but needs manual parameter settings, which could be set semi-automatically. Nevertheless, we plan to perform a detailed quantitative evaluation in the future. We want to focus, among others on evaluations with journalists adding new perspectives from a less analytical but more story-oriented side. Initial expert feedback also revealed that for detailed analysis a bird's eye perspective is needed to estimate distances on the pitch better. Additionally, coaches use two-dimensional tactic boards for manual drawings and can directly relate to the analysis results presented two-dimensionally. Another possibility for improvement is the explicit depiction of temporal details about the annotated situations.

Finally, the conceptual workflow we presented is mostly ball-centered and focuses on players in close distance to the ball. As one domain expert argued, all players on a soccer pitch are equally important and there are no less important players we can neglect. Following this argument, we should not tell only one story of a soccer match but rather one story for each of the players and one from the ball's perspective. This will result in more challenges with respect to visual representation depicting the interweaving and interdependencies of all stories.

VII. Conclusion

We presented in this paper a conceptual workflow to identify and explain aspects in team sport matches. From both, a media production and a soccer analysis perspective, the presented system provides a significant step towards automated storytelling in sports analysis. The possibility to select one particular story out of a few valuable options including the automatic visualization elements and explanations can simplify also the in-game analysis and reduce turn-around time to a few seconds. With that, mid-game analysis of journalists can be enriched with interesting and captivating content. The audio commentary as an additional communication channel between system and expert enhances the understanding being crucial because of the editorial content of the created story.

Acknowledgment

We thank our domain experts for their valuable feedback and discussions.

References

[1] M. Stein, H. Janetzko, A. Lamprecht, T. Breitkreutz, P. Zimmermann, B. Goldlücke, T. Schreck, G. Andrienko, M. Grossniklaus, and D. A. Keim, "Bring it to the pitch: Combining video and movement data to enhance team sport analysis," *IEEE Transactions on Visualization and Computer Graphics*, vol. PP, no. 99, pp. 1–1, 2017.

[2] M. Stein, H. Janetzko, T. Breitkreutz, D. Seebacher, T. Schreck, M. Grossniklaus, I. D. Couzin, and D. A. Keim, "Director's cut: Analysis and annotation of soccer matches," *IEEE Computer Graphics and Applications*, vol. 36, no. 5, pp. 50–60, Sept 2016.

[3] Z. Wang, M. Lu, X. Yuan, J. Zhang, and H. van de Wetering, "Visual traffic jam analysis based on trajectory data," *Visualization and Computer Graphics, IEEE Transactions on*, vol. 19, no. 12, pp. 2159–2168, 2013.

[4] N. Willems, H. van de Wetering, and J. J. van Wijk, "Visualization of vessel movements," in *Proceedings of the 11th Eurographics / IEEE - VGTC Conference on Visualization*, 2009, pp. 959–966.

[5] G. Andrienko, N. Andrienko, P. Bak, D. Keim, and S. Wrobel, *Visual Analytics of Movement*. Springer, 2013.

[6] T. von Landesberger, S. Bremm, T. Schreck, and D. Fellner, "Feature-based automatic identification of interesting data segments in group movement data," *Information Visualization*, vol. 13, no. 3, pp. 190–212, 2014.

[7] G. L. Andrienko, N. V. Andrienko, S. Rinzivillo, M. Nanni, D. Pedreschi, and F. Giannotti, "Interactive visual clustering of large collections of trajectories," in *Proceedings of the IEEE Symposium on Visual Analytics Science and Technology, IEEE VAST 2009, Atlantic City, New Jersey, USA, 11-16 October 2009, part of VisWeek 2009*, 2009, pp. 3–10. [Online]. Available: https://doi.org/10.1109/VAST.2009.5332584

[8] C. Perin, R. Vuillemot, C. Stolper, J. Stasko, J. Wood, and S. Carpendale, "State of the art of sports data visualization," in *Computer Graphics Forum*, vol. 37, no. 3. Wiley Online Library, 2018, pp. 663–686.

[9] T. Polk, J. Yang, Y. Hu, and Y. Zhao, "Tennivis: Visualization for tennis match analysis," *IEEE Trans. Vis. Comput. Graph.*, vol. 20, no. 12, pp. 2339–2348, 2014. [Online]. Available: http://dx.doi.org/10.1109/TVCG.2014.2346445

[10] Y. Wu, J. Lan, X. Shu, C. Ji, K. Zhao, J. Wang, and H. Zhang, "ittvis: Interactive visualization of table tennis data," *IEEE Transactions on Visualization and Computer Graphics*, vol. 24, no. 1, pp. 709–718, Jan 2018.

[11] C. Perin, R. Vuillemot, and J.-D. Fekete, "Soccerstories: A kick-off for visual soccer analysis," *Visualization and Computer Graphics, IEEE Transactions on*, vol. 19, no. 12, pp. 2506–2515, 2013.

[12] H. Janetzko, D. Sacha, M. Stein, T. Schreck, D. Keim, and O. Deussen, "Feature-driven visual analytics of soccer data," in *Proc. IEEE Conference on Visual Analytics Science and Technology*, 2014, pp. 13–22.

[13] V. Tovinkere and R. J. Qian, "Detecting semantic events in soccer games: Towards a complete solution," in *Multimedia and Expo, 2001. ICME 2001. IEEE International Conference on*. IEEE, 2001, pp. 833–836.

[14] M. Stein, J. Häußler, D. Jäckle, H. Janetzko, T. Schreck, and D. A. Keim, "Visual soccer analytics: Understanding the characteristics of collective team movement based on feature-driven analysis and abstraction," *ISPRS International Journal of Geo-Information*, vol. 4, no. 4, pp. 2159–2184, 2015.

[15] B. Lee, N. H. Riche, P. Isenberg, and S. Carpendale, "More than telling a story: Transforming data into visually shared stories," *IEEE computer graphics and applications*, vol. 35, no. 5, pp. 84–90, 2015.

[16] E. Segel and J. Heer, "Narrative visualization: Telling stories with data," *IEEE Transactions on Visualization and Computer Graphics*, vol. 16, no. 6, pp. 1139–1148, Nov 2010.

[17] "Sky go - moenchengladbach vs dortmund," http://www.skygo.sky.de/, (Accessed on January 23, 2016).

[18] "Bing text to speech api," https://docs.microsoft.com/en-us/azure/cognitive-services/speech/api-reference-rest/bingvoiceoutput, (Accessed on December 11, 2017).

[19] G. Andrienko, N. Andrienko, G. Budziak, J. Dykes, G. Fuchs, T. von Landesberger, and H. Weber, "Visual analysis of pressure in football," *Data Mining and Knowledge Discovery*, pp. 1–47, 2017.

[20] T. Boren and J. Ramey, "Thinking aloud: Reconciling theory and practice," *IEEE transactions on professional communication*, vol. 43, no. 3, pp. 261–278, 2000.