# Kickin' Scarves: Time-Oriented Visual Comparison of Soccer Trajectories

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**Figure 1:** *Screenshot of the Kickin' Scarves main view with a) the pitch display showing a selected segment of a trajectory and the color encoding of the positions, b) a search bar to search for games in the data set, c) the list of trajectories containing three games of the German national team from the 2016 european cup, d) a group of trajectory segments leading up to German goals also showing KPI for the trajectories within the group, and e) interaction options for the selected trajectory segment.*

**Abstract**

*Line-based trajectory drawings face several shortcomings in time-oriented visual comparison scenarios, primarily in their facilitation of the comparison itself as well as in their representation of time. To investigate these challenges, we perform an exploratory study focused on the application of scarf plots to the evaluation of tactics performance in soccer games. While our visual analytics prototype, Kickin' Scarves, manages to avoid the shortcomings of line-based trajectory visualizations, the application of scarf plots to real-world problems poses several design challenges that have not yet been addressed in research.*

**CCS Concepts**

• ***Human-centered computing*** → ***Visual analytics;*** *Graphical user interfaces;*

## 1. Introduction

To evaluate the success of tactics, soccer coaches must compare multiple occurrences of the same tactic throughout the games of their team. To that end, they first need to identify relevant situations (**T1**) and find all occurrences of the corresponding tactic (**T2**). Then, they must categorize the occurrences into groups of successful and unsuccessful attempts (**T3**). These groups then need to be compared (**T4**), to determine the key factors that make the difference between success and failure. Existing tools for the visual support of trajectory analysis show trajectories as lines or arrows on the playing field [AAA*21; JSS*14]. This representation is very intuitive, but it has limitations.

The first limitation is the support for visual comparison. While most research in visual trajectory analysis has focused on determining shared movement patterns [SAS*17; AAFG18; CXZ*25] or identifying spatial distributions [AA11; SJB*16; SJL*18], the visual comparison of trajectories has received less attention. As per Gleicher [Gle18], comparison can be facilitated by three visual



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representations: superposition, juxtaposition, and direct encoding. Direct encodings are only applicable to pairwise comparisons and thus not useful for the comparison of many trajectories. In addition, both the superposition and juxtaposition of line-based trajectory drawings cause difficulties due to the visual complexity of a trajectory. Superposition-based approaches lead to clutter with many or complex comparison elements. Juxtaposition-based approaches make it difficult to find the differences, because the size of the differing parts may be small relative to the overall size of the objects. A further limitation of line-based visualizations of trajectories is the representation of time, because this representation only allows the inference of order. To compensate, several approaches have tried to incorporate time via supplemental channels such as color [BDP10], animation [BTD14], or separate timelines [AAA*21]. However, in a real-time competitive scenario like soccer, timing and speed can make a large difference. For example, a quick counter attack can only work, if the opposing team does not have the time to reposition. The importance of timing in such scenarios necessitates a more prominent consideration of time during analysis.

To address these limitations, we explore a different design approach: using scarf plots to visually compare soccer trajectories. Scarf plots are a visualization technique usually applied to the analysis of eye-tracking studies [RD05]. They encode the two spatial dimensions with color and the temporal dimension along the x-axis. Using only one display dimension for the encoding makes juxtaposition-based designs naturally applicable to scarf plots. Yet the analysis power of scarf plots has so far rarely been demonstrated for trajectories other than eye-tracking [KHH*15; CAMR20]. These considerations yield our following research questions:

- Can scarf plots be successfully employed to facilitate time-oriented visual trajectory comparison in other domains?
- What are the main limitations of scarf plots in real-world analysis scenarios?
- Which visual interactive techniques can be applied to augment scarf plots' analysis capabilities?

## 2. Design Rationale

One of the most important decisions for scarf plot-based designs is the applied color map. Inspired by the use of continuous color maps for scarf plots by Andrienko et al. [AACF22], we decided to also represent the continuous coordinates on the playing field with a continuous 2D color map. Based on the investigation by Bernard et al. [BSM*15], we selected the color map *Teuling Fig.3*, because it showed the best performance for a variety of analysis tasks. To act as legend for the colors, Kickin' Scarves displays the pitch on the left side of the screen (Figure 1 a)). However, we found that this choice of color map leads to visually too dense and overwhelming scarf plots, when viewing the entirety of a game. To improve upon this, we must provide users with multiple levels of detail in the future. This could potentially be achieved by flexibly tailoring the color map to the specific analysis scenario. As first step toward this goal, we enable users to toggle the color encoding between the absolute positions on the pitch and relative movement vectors. An example screenshot of this display mode can be found in the supplemental material.

The main portion of the Kickin' Scarves interface is dedicated to the scarf plots themselves (Figure 1 c)). Kickin' Scarves is based on the publicly available position-annotated soccer event data set by Papparlardo et al. [PCR*19], from which we extract the ball's trajectory for each game. To analyze individual game situations (**T2**), trajectory segments can be extracted interactively by selecting a time period, and clicking the *bookmark* icon that appears below the selection (Figure 1 e)). The manual selection of suitable segments is a tedious process, which we need to ease in the future by providing the means to automatically extract situations via user-defined rules [Cv18] or sketches [SSN*16].

We also discovered interpretability to be a significant challenge for our scarf plot-based design. While line drawings intuitively communicate what is happening on the pitch, scarf plots require users to mentally translate the colors to positions first. To enable the identification of relevant game situations (**T1**), we enhance interpretability through several interactions. First, users can chose to display specific events from the original time-stamped event data alongside the scarf plots. Second, users can select segments of scarf plots to view as line drawing on the pitch. Likewise, users can create a drag-box selection across the pitch to highlight the sections of scarf plots in that area.

To ease the search for suitable comparison candidates (**T3**), we also provide a similarity search feature. After selecting a game situation of interest, users can click the *search* icon to find similar trajectory segments (Figure 1 e)). The search uses a sliding window approach to find trajectories with high similarity to the query segment. We compute similarity in terms of the time warped edit distance [Mar09] with a piecewise aggregate approximation of the original position data [KP00], which extracts the ball position in regular one-second intervals. We selected this distance measure, because it can capture both spatial as well as temporal dissimilarities between the trajectories.

For the grouped comparison of similar situations (**T4**), users can create such groups via drag-and-drop (Figure 1 d)). For each group, we also display distributions of KPI within the group, to allow a quick comparison of statistics.

## 3. Conclusion

We have presented the challenges of traditional line-based drawings for the visual comparison and causality analysis within soccer trajectories. Further, we have presented Kickin' Scarves, our exploratory design prototype to address these limitations. We have also identified new research challenges that have to be investigated to enable the use of scarf plots for real-world analysis problems.

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