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MODELING SOCCER BY MEANS OF RELATIVE PHASE

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Abstract Soccer is a complex system. Therefore, appropriate (nontrivial) models have to be applied to be able to analyze the behavior of the teams on the pitch. This study analyzed the World Cup Final 2006 between France and Italy by means of relative phase. Mean longitudinal and lateral positions of all 20 outfield players were used to calculate relative phase by Hilbert transformation. Whole team-, group-, and attacker-fullbacks couplings showed that soccer is clearly an in-phase game. Perturbations of the relative phase structure helped to identify scoring opportunities of the attacking team. Moreover, analyses of the relative phase structure can help to understand the complexity of soccer.

Key words Perturbations, relative phase, soccer.

1 Introduction

In order to be able to improve the performance of athletes, the sport itself has to be modeled in an appropriate way. Based on the skills and abilities of the athlete, the analyses of the performance during single-athlete individual sports (without interaction process with an opponent) work mostly easy, because the performance is determined by those skills and abilities. However, analyses of team sports and multi-athletes individual sports (including interaction processes with an opponent) are far more difficult. This is due to the dynamical structure of those sports. Two sub-systems (e.g., different teams) try to achieve their own goal (as an attractor) and at the same time try to prevent the opponent sub-system to do so. Analyses of performance in these sports need to be based on appropriate models reflecting these characteristic properties.

There have been many studies analyzing the performance during individual sports with opponent interaction using different modeling techniques. In handball, moving correlations and random walk proved to be a helpful way to analyze momentary strength of teams during a match[1]. In soccer, the analysis of geometrical centers (mean longitudinal or lateral position of players), expansion speeds, and possession functions gave some information about the performance during a match, but some methodological decisions limited the significance of the analyses. For example, the goal keepers were included for calculation of geometrical centers (mean longitudinal and lateral position of players), and therefore, the expansion speeds (as changes of geometrical centers over time) were also negatively affected by this, as the goal

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keeper does not perform in the same way outfield players do[2]. Nevertheless, the results of the study were promising for analyzing the complexity of soccer and showed that there is a need for appropriate models in soccer research. A similar approach analyzed the centroids positions (mean longitudinal and lateral position of players) of all outfield players during 5 vs 5 matches and the surface areas of the teams (space covered by the teams)[3], by means of Pearson's correlation coefficients and showed a strong coupling between the centroid positions and surface areas of both teams during match-play. Moreover, for some goals scored during the match, centroid position of the attacking team caught up the centroid position of the defending team. This could be an indication for a specific tactical behavior, which can be identified by such coupling analyzes.

This approach aimed at the interactions of the teams and therefore focused on the dynamical system approach. Another method to analyze the coupling of competing teams or players is relative phase. The relative phase is a complex variable that allows analyzing spatial-temporal relations between two oscillating agents by means of quantitative values. In-phase (0°) and anti-phase (180°) are the two main phase relations that can be observed, representing the relations of the places of the agents (in-phase = same place, anti-phase = opposite place) in their specific cycles.

This method was applied in many sports during the last years. For example, in squash and badminton most of the playing time, athletes show anti-phase behavior[4,5]. Moreover, there is consensus that in tennis both, in-phase (during long-line rallies), and anti-phase behavior (during cross-hand rallies) can be found[5−7]. A study on basketball[8,9] analyzed match sequences by means of relative phase, too. Intra-coupling (players of the same team), as well as inter-coupling (players of different teams) were analyzed. Intra-coupling was more distinct for one team, than for the other teams, suggesting that this is an indicator for more patterned behavior of the team. A strong in-phase was found for longitudinal direction for both, intra- and inter-coupling. Based on the dynamical system theory, the results of this study[8,9] helped to describe the performance of the analyzed basketball teams.

Another study[10] analyzed movement behavior of futsal players during special sub-phases of a match. The results showed that defenders were performing in-phase behavior between themselves as well as with the ball, whereas attackers showed to be less coupled. The authors suggested this to be evidence for a self-organizing process leading into the coordinated behavior patterns shown on the pitch.

Therefore, relative phase seems to be an appropriate method to analyze team sports behavior and performance. The present study wants to apply the method of relative phase to soccer, give first results for team-, groups-, and single player-couplings, and discuss the applicability of the method.

2 Method

Positional data of 22 players in the 2006 final of FIFA World Championship between Italy and France were recorded with 25 Hz using image processing techniques[11]. The relative phase was calculated by using the Hilbert Transformation (Matlab) on values aggregated to 1 Hz (the Hilbert transformation is used to calculate an analytic signal in order to provide true measures for the phase and the amplitude of a signal; for detailed information read [6]. For whole-team analyses, mean team centers and range (difference between max and min position of players except goalkeeper) were calculated for x- and y-direction. For groups of players or single players analyses only the mean centers in longitudinal direction were calculated. Those values were used as input values for the Hilbert Transformation. Tightness of coupling was analyzed by means of standard deviation of relative phase values. Three calculations were made: 1) relative phase for both teams, 2) relative phase for the midfielders of both teams, and 3) relative phase for attacker-fullbacks couplings.

Because substitutions could change the tactical formation of the teams, the analyses focused on the first half of the match where no substitutions occurred.

3 Results

3.1 Team Coupling

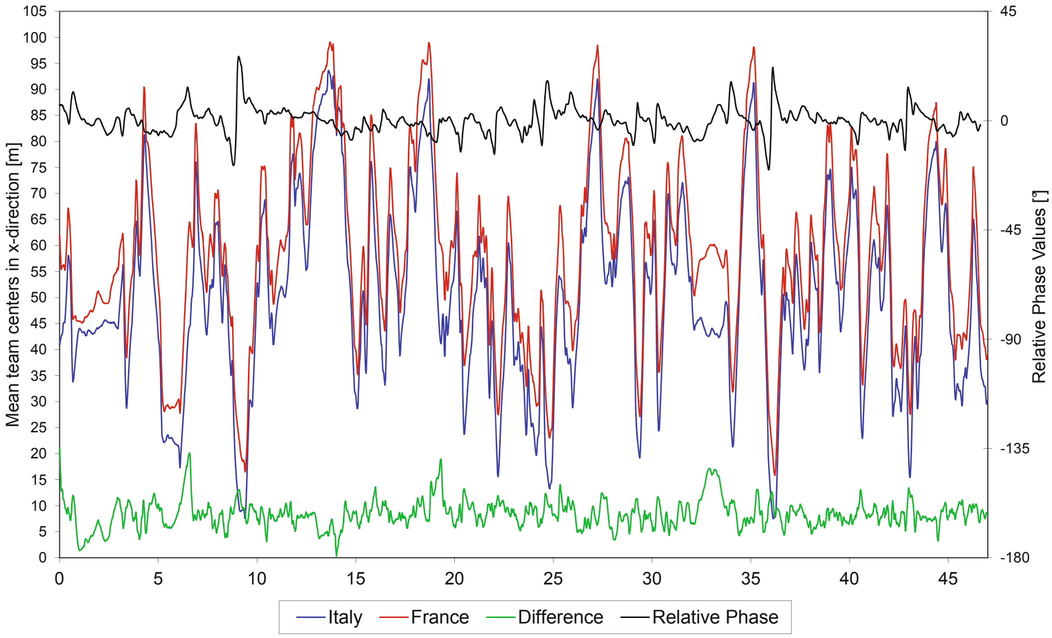

Figure 1 Longitudinal team centers and relative phase for Italy and France during the first half of the final 2006

Figure 1 shows the mean longitudinal team centers for both teams in the first half of the world cup final 2006. A tight coupling between both teams in this half was found. Mean and standard deviation of their relative phase were RP=0.00 ± 5.25°, respectively. There were three main perturbations (disturbance of a stable phase structure) of the in-phase structure. The first (minute 6) was the penalty kick leading to the 1-0 for France. Second, appearing in minute 19 was the goal by Italy to the 1-1. In minute 33 the third perturbation was an injury of an Italian player lasting for more than one minute. This time was used by the players to walk to the outline for drinking or for getting instructions by the coaches.

An overview to the mean lateral team centers is given by Figure 2. The coupling of the lateral centers was even tighter (RP=0.00 ± 3.84°) than the longitudinal one. The main perturbations (minute 6 and 33) of the in-phase structure of the lateral team centers are caused by the same events as in the longitudinal analyses. Different to the tight coupling of the team's centers, the coupling of the longitudinal (RP=0.13 ± 18.32°) and lateral (RP=0.13 ± 18.25°) team's ranges was weaker. Therefore, a clear identification of perturbations was impossible.

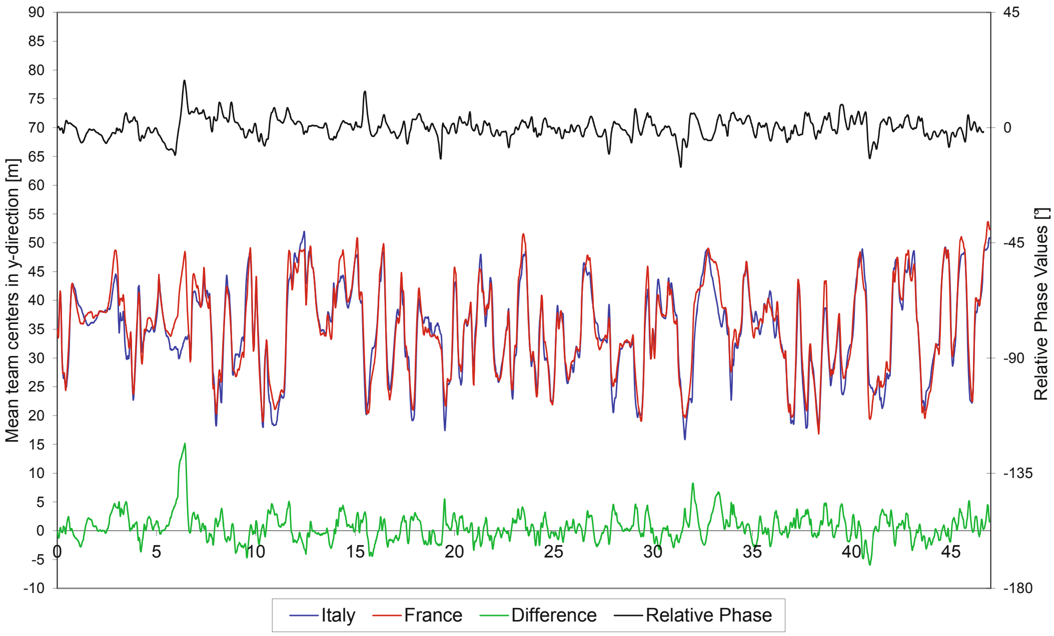

Figure 2 Lateral team centers and relative phase for Italy and France during the first time of the final 2006

3.2 Group Coupling

The analysis of the coupling of midfielders (RP=$0.00 \pm 5.40°$) was similar to the whole team coupling. Nevertheless, the relative phase values showed a higher sensitivity to changes in the behavior of the players (see Figure 3). For example the perturbation between minute 8 and 9 was an attack by the French team after a free kick, leading into a scoring opportunity and resulting in a corner kick. In minute 36, again the French team had a scoring opportunity created by one of the French midfield players.

3.3 Single Player Coupling

The analysis of attacker-defender-coupling is shown in Figure 4. There are three main perturbations of the in-phase (RP=$0.00 \pm 11.22°$) relation. Already mentioned and visible in Figure 3 the first perturbation was the scoring opportunity for France in minute 9. The second perturbation in minute 24 was a dribbling of the French attacker, leading into a scoring opportunity for France. Finally, in minute 43, the French attacker enters the box, while the defender helps to tackle an opponent on the side of the pitch and therefore did not follow the attacker.

The coupling of the Italian attacker and the French defenders was even tighter (RP=$0.00 \pm 6.55°$). Two main perturbations could be identified. First the already mentioned scoring opportunity for France in minute 9 (The French defender left his position and joined in the attack). Second, after a failed attack by Italy, the French defenders move towards the halfway line, while the Italian attacker stays close to the penalty box.

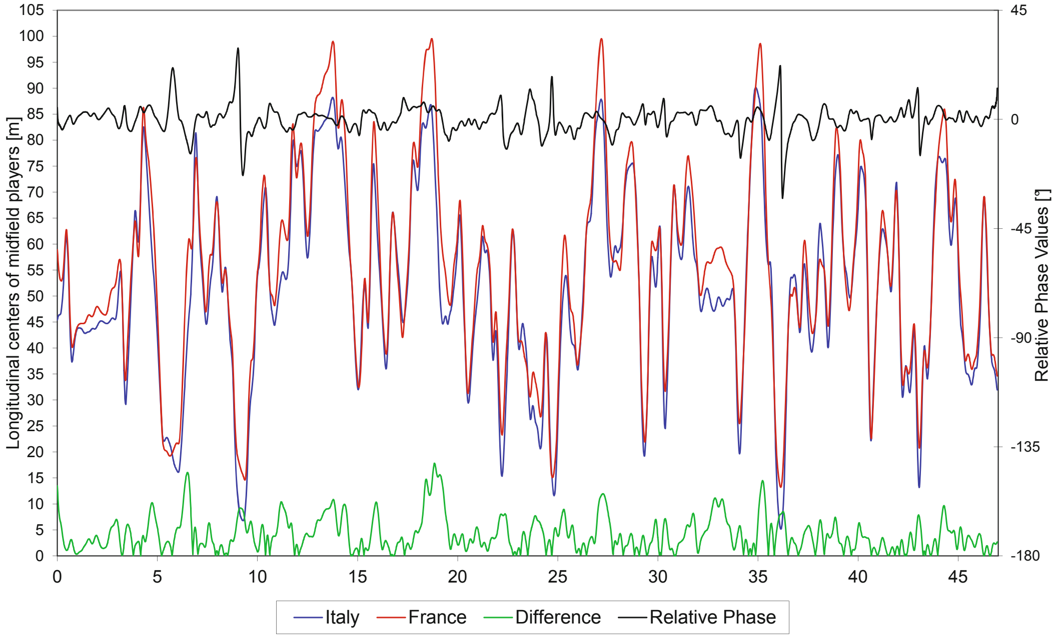

Figure 3 Longitudinal centers of midfield players and relative phase during the first half of the final

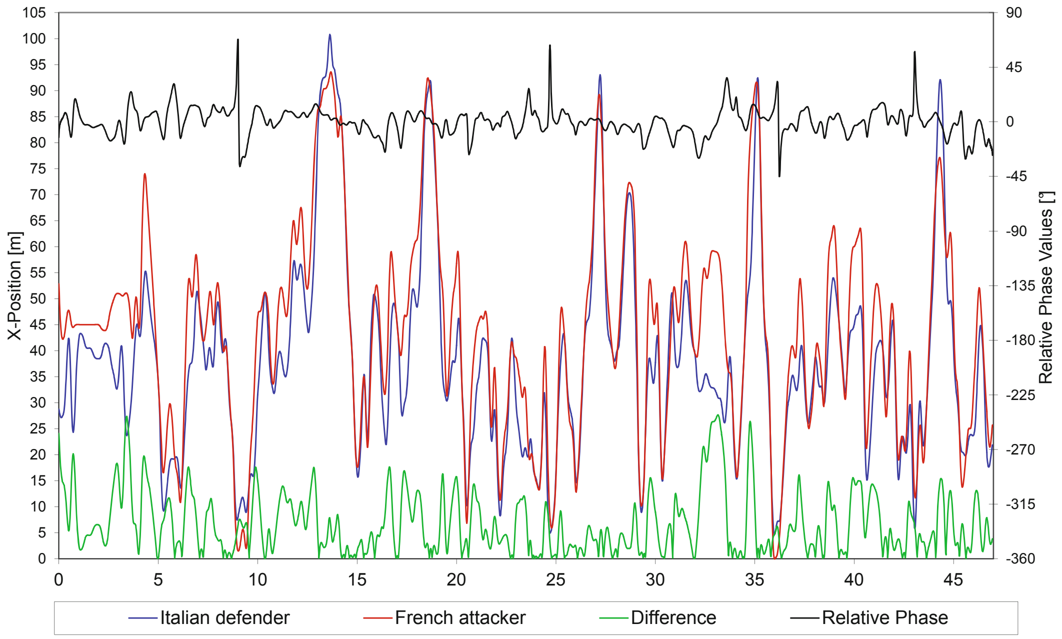

Figure 4 X-Positions of French attacker and Italian defender and relative phase in the first half of the final

4 Discussion

This is one of the first studies to analyze soccer by means of relative phase. Results showed that the method of relative phase analysis is appropriate to create valuable information about the dynamical system soccer. The analyses focused on team-, group-, and single-player-couplings. Whole team analyses clearly pointed out, that soccer is characterized by an in-phase structure, meaning a coupled movement of teams, groups or single players during a match. From a practical point of view, this is not surprising, because the defending team always has to react on the movement of the opponent in order to be able to disturb their attacks or to prevent them from scoring a goal. Contrary to tennis[1], there are no changes of the relative-phase structure itself. Consequently, no anti-phase structure was found during the analyses. However, there were perturbations of the in-phase structure.

Analysis of perturbations (especially in the group- and single-player-coupling) in the in-phase coupling can help to understand and simplify the complexity of soccer. For example, such perturbations can be used to identify playing situations in which one team attacked in a way, which the defending team was not able to answer in the needed manner, resulting in a scoring opportunity for the attacking team. However, there are still some aspects and parts in the relative phase, which are not fully understood, yet. Nevertheless, for the purpose of describing and analyzing specific match play situations, relative phase analyses hold have potentials. Future studies should make use of the method of relative phase and focus on the analysis of group- and single-player couplings. A formal definition of perturbations would be a benefit for these studies.

Compared to different modeling approaches of soccer, the relative-phase analysis is the only one to allow analyses of the coupling between teams, groups, or players. Relative-phase should be calculated by Hilbert transformation because this allows dynamic analyses including the study of perturbations of relative phase. Using correlations is a static procedure[3], even if a moving average of the correlation over the whole match is calculated as it is suggested in [1]. Therefore, future analyses of the complexity of the dynamical system soccer should make use of the relative phase analysis by means of Hilbert transformation in order to get valuable and important information on coupling and its perturbations in the game.

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