TRACKING MULTIPLE HANDBALL PLAYERS USING MULTI-COMMODITY NETWORK FLOW FOR ASSESSING TACTICAL BEHAVIOUR

António Manuel Marques de Sousa Alves Lopes[1,2], João Manuel Eleutério Florêncio[2], Horesh Ben Shitrit[3], Pascal Fua[3], Sofia Cristina Carreiras Fonseca[1]

[1]Faculty of Physical Education and Sport of Lusófona University, Lisbon, Portugal

[2]Portuguese Handball Federation, Lisbon, Portugal

[3]Computer Vision Laboratory of École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland

Summary

The aim of this work is to present an approach that can help to characterize teams' and players' tactical behavior using two techniques to aid handball coaches to assess tactical procedures when using spatial measures derived from players position data. Results suggest that it is possible to identify tactical spatial differences between fast-break and fast throw-off. The approach presented in this work may be useful to reduce the time spent in game analysis and to improve coaches' assessment of tactical performance during the training sessions.

Keywords: handball, tracking multiple players, spatial measures, Voronoi diagrams, tactical assessment.

Introduction

Handball is a professional team sport to which little scientific investigation has been dedicated, regarding tactical performance analysis, despite the growing interest of many research areas on studying players' behavior and teams' dynamics[1,2]. Unlike recent studies in other team sports, such as soccer[3] and basketball[4], where modern and innovative approaches are considered, in handball, and to the best of our knowledge, most of the research studies consider a descriptive analysis of the game[5]. Commonly, a notational data analysis[6] is performed and a set of categories is considered to classify the observed actions of the players during the game, being this particularly focused on the player with the ball (e.g., where he/she is in the field, to whom he/she passes the ball, where in the goal he/she shots the ball), disregarding other sources of information that may influence the course of the action, such as the position of the teammates and opponents as well the tactical context of the play. Despite limitations of this kind of analysis for assessing teams' and players' performance, these categories are still used[7,8] and regarded as reliable indicators for handball experts' performance analysts (e.g. EHF Periodical[9]).

With the advances of technologies, there are now a number of systems that allow capturing other types of data[10] from matches or training sessions. In particular, positional data can be made available for academic research purposes by means of, for example, Ubisense tracking system[10], which allow a different approach for analyzing teams' and players' performance. The analysis of positional data has been recognized as a promising way to study in depth performance in team sports[2,11], and many authors have already considered these data for theoretical approaches in a few sports, such as basketball[4], football[12], futsal[13] and rugby[14]. Although these studies have demonstrated the potential of this analysis in assessing teams' and players' performance, the scientific nature of the whole work do not allow a clear understanding of the game by the sports agents of interest, mainly coaches. Thus, a more practical approach is required when considering these powerful data, which is an essential tool for, not only acquiring team sports' performance, but also identifying well-known game principles[15].

This exploratory research presents a preliminary summary of two novel techniques applied to handball in order to help coaches assess tactical procedures in training sessions: (1) a multi-commodity network flow to track multiple handball players and collect players' trajectories and, (2) a spatial approach for analyzing players' positional data and describing the interaction behavior of attack and defense teams when considering different transition tactics, fast-break and fast throw-off.

Methods

Study design

A mixed method study design[16] has been used considering both qualitative (classification of the sequences in two categories using observational methodology[17]: fast-break and fast throw-off) and quantitative data (positional data from each player).

Sample

In a training session of the Portuguese women's handball national team, an exercise of attack transition after goal was recorded. The exercise was played during 15 minutes in half court (20m×20m) in a 6×6+GK situation. At the signal of the coach, players would perform one of two types of transition – fast-break or fast throw-off. During the whole session, players' position was tracked using the registry of only one video camera, as described below. A sequence of each type of transition was considered for this study.

Tracking system

The ground floor of the handball court was represented as a grid of cells with a resolution of 20cm×20cm. The goal of the system is to estimate, at each frame, which grid cells are occupied and by whom. The system is composed of three core components: detection, identification and tracking. Detection is based on a generative model which can effectively handle occlusions in each time frame independently. This produces a Probability Occupancy Map (POM). The detection algorithm is developed for multiple people detection from multiple cameras[18] and also applicable for a single camera as well[19]. The detected location of the people are then used by the next components of the tracking system. The identification component recognizes the identity of the person according to his color histogram, facial descriptor and his/her jersey number. In our case, we used only the shirt colors in order to distinguish between the role of the players (attack and defense). In the final tracking component, the multi-people tracking problem is formulated as a multi-commodity network flow problem[20,21]. The tracker links the detections of people in individual frames across time, while taking into account the appearance and identity constraints, obtaining the players' trajectory movement.

Spatial assessment

Players' positional data collected on both sequences (sequence 1: fast-break and sequence 2: fast throw-off) were considered to calculate spatial metrics to describe the behavior of attack and defense teams, namely, the area of the convex-hull[15], the area of the bounding rectangle[15] and the Voronoi area[22], all reported in % relative to the field area and calculated using routines implemented in Matlab R2008a software. These represent the % of covered area by each team.

Results and Discussion

The aim of this exploratory study was to apply a novel tracking system to gather positional data from handball players during a training exercise of transition (fast-break and fast throw-off) and to characterize teams' tactical behavior by means of spatial metrics derived from their trajectories.

Next are presented each of the metrics mentioned above calculated for each team and for each sequence. Note that the first sequence was a fast break (sequence 1) that involved several attacking players, all of them starting the sequence in the center of the court except for both wing players that were already set in specific positions; the second sequence corresponded to a fast throw-off (sequence 2), also involving several attacking players, but in this case all players, including the wingers, started the sequence behind the midfield line. In both sequences, the defender players are in position using a 6:0 defense system. The figures below describe the evolution of the % of covered area, assessed by different spatial measures, across the duration of each sequence, for the attack and defense teams, in grey and black solid lines, respectively.

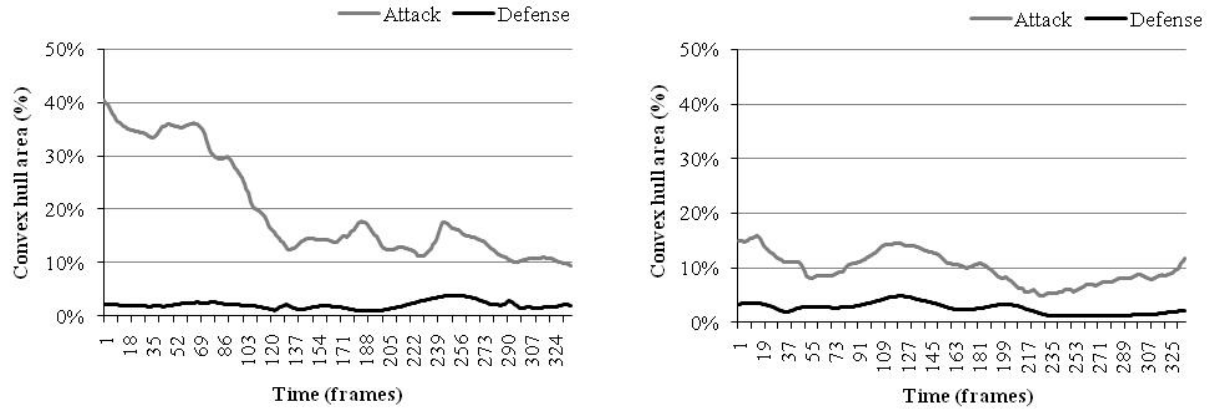

Figure 1: Convex-hull area (in percentage of field area) calculated for the attack and defense teams in sequence 1: fast break (left) and sequence 2: fast throw-off (right)

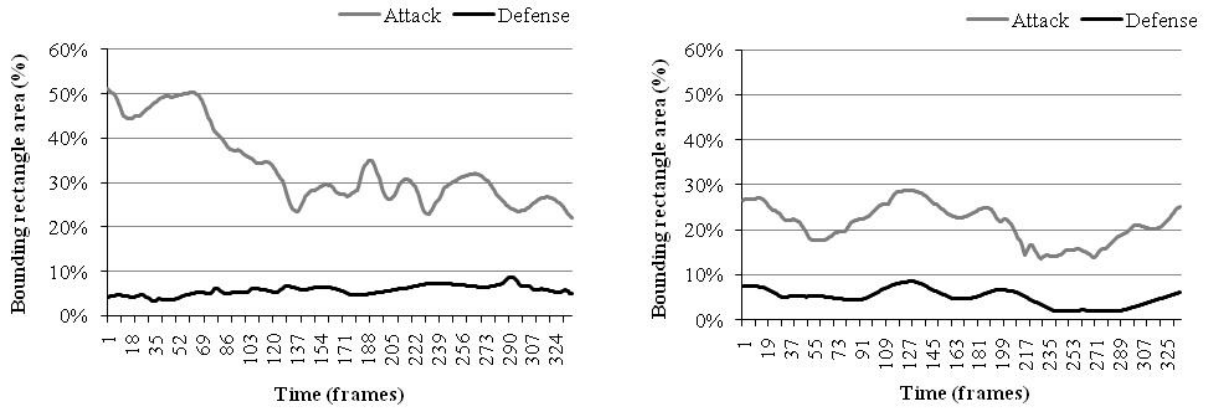

Figure 2. Bounding rectangle (in percentage of field area) calculated for the attack and defense teams in sequence 1: fast break (left) and sequence 2: fast throw-off (right)

When considering the convex-hull and bounding rectangle areas, in Figure 1 and Figure 2, respectively, it is clear that the % of covered area of the defending team is, across the whole time and for both sequences, lower than the attacking team, being this in accordance with game principles. In addition, the % of covered area for the attack tends to decrease as they get closer to the defenders, presenting more and higher fluctuations in comparison with the defense team. This might have to do with the use of the 2nd pivot or the changes or combinations between

backcourt players and the pivots, with the defense team trying to maintain their defense system with the same structure. Regarding the difference between the two types of transition (fast break vs. fast thow-off), it is clear that in the beginning of sequence 1 (fast break), the attacking team covers more space, as the wingers are further from the other teammates. But, in the course of the sequence, this distance decreases and, consequently, the area occupied by the attack also decreases. In sequence 2 (fast throw-off), the % of covered area for the attack is, across the whole time, considerably smaller, as the players progress in the field, exploring it more in width than in depth.

Although both of these measures give relevant information about the evolution of the % of area occupied for each team and are able to capture the differences between the two modes of transition after goal, they present some of the same limitations previously identified in other team sports[15,23,24], in particular, the dimensions of the playing area and the possibility of having teams' convex-hull/bounding rectangle overlapped are disregarded. Since the Voronoi diagram approach appears to overcome these specific limitations, it was also considered here (Figure 3, below). This spatial tessellation considers the playing area (excluding restricted areas as the GK area in this particular sport) and divides it into cells, each "owned" by one and only one player, here designated Voronoi area (VA). The % of covered area (%VA) for each team is the sum of the area of the cells associated to the respective players.

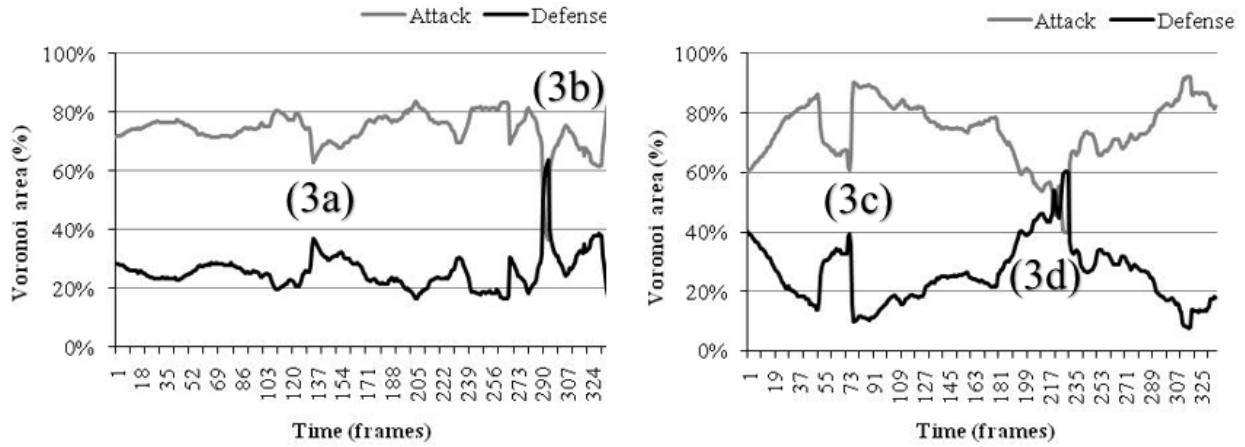

Figure 3. Voronoi diagram (in percentage of field area) calculated for the attack and defense teams in sequence 1: fast break (left) and sequence 2: fast throw-off (right)

In opposition to what was observed in the previous spatial measures, the Voronoi area occupied by both teams represents the whole playing area, according to definition of the spatial model itself. Consequently, the increase of the area by one team implies a decrease of the area of the other. Similarly to the previous metrics, the attack team covers more area than the defense team, but unlike those, this is not maintained through the whole sequence. With this approach it is possible to identify moments when the space dominance is somehow balanced (~50% each team) and moments when a sudden dominance of the defense team is observed. These sort of variations seem to be associated with specific collective and individual actions that aim to disrupt the shape and organization of the defense system (Figure 3): (a) the attacking makes the pivot come out from the inside of the defense or makes it cross, and a defender goes out with her until the delivery to a teammate; (b) this type of perturbation reveals that the attacking team went inside the defense in penetration (using or not a two pivot displacement, trying to attract the defenders to outside their zone) and tried to score, and did not make it through, but then again they still maintain the ball possession until the end of the sequence where they attempt to score; (c) the defense team tries to anticipate them attacking movement and this latter team spread out around the field in width and in depth to break the defense team in two parts, and then strengthening the

attack in depth; (d) give origin to 2×2 and 1×1 combinations inside the 9m with the defending team trying to intercept the ball.

Conclusions

Handball is a team sports characterized by a fast intertwined and dynamic interactions between players, and a deeper understanding of this complex dynamic spatial interaction is required in order to serve the interests of both academic and sports agents. In this paper, three spatial metrics are presented with the aim of addressing the above problem. From the results of this experimental study, where an actual handball exercise was considered, it was found that the %VA could be used to quantitatively and qualitative describe the tactical behavior of the two teams in two distinct types of transition. This exploratory work is small yet, but the results are pointing towards the right direction, i.e., the analysis matches what coaches recognize as relevant to describe and identify tactical concepts in handball. Still, and although the Voronoi approach overcomes some limitations of other spatial measures, it presents other limitations that might be overcome using some suggestions in the work developed by Taki, and Hasegawa[25] in order to capture more of the functional and dynamical behavior of each player and team during performance.

Acknowledgements

The first author gratefully acknowledge the support of the Spanish government project Observación de la interacción en deporte y actividad física: Avances técnicos y metodológicos en registros automatizados cualitativos-cuantitativos (Secretaría de Estado de Investigación, Desarrollo e Innovación del Ministerio de Economía y Competitividad) during the period 2012-2015 [Grant DEP2012-32124].

References

1. Emmerik REA Van, Rosenstein MT, Mcdermott WJ, Hamill J. A Nonlinear Dynamics Approach to Human Movement. *Nonlinear Dyn.* 2004;20(4):396–420.

2. Glazier P, Davids K, Bartlett R. Dynamical systems theory: a relevant framework from performance-oriented sports biomechanics research. *Sport Sci.* 2003;7:85–92.

3. Bartlett R, Button C, Robins M, Dutt-Mazumder A. Analysing Team Coordination Patterns from Player Movement Trajectories in Soccer: Methodological Considerations. *Int. J. Perform. Anal. Sport*. 2012;12(2):398–424.

4. Bourbousson J, Sève C, McGarry T. Space-time coordination dynamics in basketball: Part 2. The interaction between the two teams. *J. Sports Sci.* 2010;28(3):349–358.

5. Hughes M, Franks I. *Notational Analysis of Sport: Systems for Better Coaching and Performance in Sport*. 1ª ed. London: Routledge; 2004.

6. Hughes M, Bartlett R. The use of performance indicators in performance analysis. *J. Sports Sci.* 2002;20(10):739–754.

7. Meletakos P, Vagenas G, Bayios I. A multivariate assessment of offensive performance indicators in Men ' s Handball : Trends and differences in the World Championships. *Int. J. Perform. Anal. Sport*. 2011;11:284–294.

8. Rogulj N, Vuleta D, Milanović D, Čavala M, Foretić N. The efficiency of elements of collective attack tactics in handball. *Kinesiol. Slov.* 2011;17(1):5–14.

9. Pokrajac B. EHF Men's Euro 2008 – Analysis, discussion, comparison, tendencies in modern handball. *EHF Period.* 2008.

10. Leser R, Baca A, Ogris G. Local Positioning Systems in (Game) Sports. *Sensors*. 2011;11:9778–9797.

11. Reed D, Hughes M. An Exploration of Team Sport as a Dynamical System. David Reed and Mike Hughes. Centre for Performance Analysis, School of Sport, Physical Education and Recreation, University of Wales Institute Cardiff, Cyncoed Campus, CF23 6XD. *Int. J. Perform. Anal. Sport*. 2006;6(2):114–125.

12. Headrick J, Davids K, Renshaw I, Araújo D, Passos P, Fernandes O. Proximity-to-goal as a constraint on patterns of behaviour in attacker-defender dyads in team games. *J. Sports Sci.* 2012;30(3):247–53.

13. Travassos B, Araújo D, Correia V, Esteves P. Eco-Dynamics Approach to the study of Team Sports Performance. *Sci. York*. 2010;3:56–57.

14. Passos P, Araújo D, Davids K, et al. Interpersonal pattern dynamics and adaptive behavior in multiagent neurobiological systems: conceptual model and data. *J. Mot. Behav.* 2009;41(5):445–59.

15. Lopes A, Fonseca S, Leser R, Baca A. Part 7 - Systems - 36. Using spatial metrics to characterize behaviour in small sided games. In: Peters D, O'Donoghue P, eds. *Performance analyis of sport IX*. London: Routledge; 2013.

16. Camerino O, Castañer M, Anguera MT. *Mixed Methods Research in the Movement Sciences: Cases in Sport, Physical Education and Dance*. UK: Routledge; 2012.

17. Teresa M, Argilaga A, Villaseñor AB, Hernández A, Luis J, López L. Diseños observacionales: ajustes y aplicaciones en psicologia del deporte. *Cuad. Psicol. del Deport.* 2011;11(2):63–76.

18. Fleuret F, Berclaz J, Lengagne R, Fua P. Multicamera people tracking with a probabilistic occupancy map. *IEEE Trans. Pattern Anal. Mach. Intell.* 2008;30(2):267–82.

19. Ben Shitrit H, Raca M, Fleuret F, Fua P. Tracking Multiple Players using a Single Camera. *Mach. Vis. Appl.* 2013:14.

20. Shitrit H Ben, Berclaz J, Fleuret F, Fua P. Tracking Multiple People under Global Appearance Constraints. In: *IEEE International Conference on Computer Vision (ICCV)*. Barcelona: Spain IEEE; 2011:137–144.

21. Ben Shitrit H, Berclaz J, Fleuret F, Fua P. Multi-Commodity Network Flow for Tracking Multiple People. *IEEE Trans. Pattern Anal. Mach. Intell.* 2013.

22. Kim S. Voronoi analysis of a soccer game. *Nonlinear Anal. Model. Control*. 2004;9:233–240.

23. McGarry T. Applied and theoretical perspectives of performance analysis in sport: Scientific issues and challenges. *Int. J. Perform. Anal. Sport*. 2009;9(1):128–140.

24. Fonseca S, Milho J, Travassos B, Araújo D, Lopes A. Measuring spatial interaction behavior in team sports using superimposed Voronoi diagrams. *J. Perform. Anal. Sport*. 2013;13(1):179–189.

25. Taki T, Hasegawa J. Quantitative measurment of teamwork in ball games. *Int. Arch. Photogramm. Remote Sens.* 2000;XXXIII(1992):125–131.