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Preface

The 10th International Symposium of Computer Science in Sport (IACSS/ISCSS 2015), sponsored by the International Association of Computer Science in Sport and in collaboration with the International Society of Sport Psychology (ISSP), took place between September 9–11, 2015 at Loughborough, UK. Similar to previous symposia, this symposium aimed to build the links between computer science and sport, and report on results from applying computer science techniques to address a wide number of problems in sport and exercise sciences. It provided a good platform and opportunity for researchers in both computer science and sport to understand and discuss ideas and promote cross-disciplinary research.

This year the symposium covered the following topics:

- Modelling and Analysis
- Artificial Intelligence in Sport
- Virtual Reality in Sport
- Neural Cognitive Training
- IT Systems for Sport
- Sensing Technologies
- Image Processing

We received 39 submitted papers and all of them underwent strict reviews by the Program Committee. Authors of the thirty-three accepted papers were asked to revise their papers carefully according to the detailed comments so that they all meet the expected high quality of an international conference. After the conference selected papers will also be invited to be extended for inclusion in the IACSS journal.

Three keynote speakers and authors of the accepted papers presented their contributions in the above topics during the 3-day event. The arranged tour gave the participants an opportunity to see the Loughborough University campus, and facilities in the National Centre for Sport and Exercise Medicine and the Sports Technology Institute.

We thank all the participants for coming to Loughborough and hope you had enjoyed the event. We also thank the Program Committee members, the reviewers and the invited speakers for their contributions to make the event a success.

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- Prof. Thomas Schack, Bielefeld University, Germany

Soccer analyses by means of artificial neural networks, automatic pass recognition and Voronoi-cells: An approach of measuring tactical success.

Jürgen Perl, University of Mainz

Daniel Memmert, German Sports University Cologne

Abstract. Success in a soccer match is usually measured by goals. However, in order to yield goals, successful tactical pre-processing is necessary.

If analyzing a match with the focus on "success", promising tactical activities including vertical passes with control win in the opponent's penalty area have to be the focus. Whether or not a pass is able to crack the opponent's defence depends on the tactical formations of both the opponent's defence and the own offence group.

The methodical part of the contribution consists of three steps:

(1) The first step describes how to analyze the formations of tactical groups by means of an artificial neural network, which is integrated in the *DyCoN*-tool. I.e. the positions of the players are condensed to those of tactical groups, and the formations of the tactical groups are mapped to a small number of characteristic patterns. In this way, the teams' activities can be reduced to interactions of tactical patterns, making it much easier to automatically detect regular and/or striking tactical features. Those tactical features build the context for measuring success, as described in the following steps:

(2) Successful passes from a passing to a receiving player of a team are necessary preconditions for opening or continuing successful attacks. The software *SOCCER* is able to automatically calculate those passes based on the position data of the players and the ball. Along with the information from (1) it can be recognized, which types of formation interaction are helpful for generating successful or "dangerous" passes.

(3) Up to this point, "successful" just means that the receiving player effectively achieves control of the ball. Based on the Voronoi-approach, the pass is seen as more successful and actually "dangerous", if it causes a higher rate of spatial control in the opponent's penalty area. The *Voronoi*-tool calculates tactical space control and therefore helps to measure the tactical success of a pass.

The combination of the described steps of automatic position-based analyses can be helpful for a deeper understanding of match dynamics and measuring tactical success.

The tools *DyCoN*, *SOCCER* and *Voronoi* have been developed by J. Perl, University of Mainz, in cooperation with D. Memmert, DSHS Cologne.

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1 Introduction

The basic idea of SOCCER (Perl & Memmert, 2011; Grunz, Memmert & Perl, 2012) is to reduce the complex match dynamics to the main tactical states and transitions. This approach is adopted from technical process analysis in which proceeding steps are defined by context-depending transitions of states, based on current states and conditions. Doing it this way, a process can not only be planned, described and analyzed but also be simulated for tactical optimization.

Since the late 1970s, it has been the idea of one of the authors (Perl) to apply this approach to sport games and in fact he was successful for instance in applying this to tennis. The main problem, however, was the lack of data. Particularly in case of soccer the process dynamics is highly based on the positions of the players and the ball – and all analysis approaches remained to be academic as long as such data was not easily available.

Since about 2010 the situation has changed a lot due to new position data recording technologies. Achieving information from that data turned out to be the main problem now.

In a first step, trivial information like speed or running distances of the players can be calculated which, however, does not help that much in order to understand tactical concepts.

In the SOCCER-project the positions of the players are condensed to those of tactical groups. The time-depending sets of the players' positions of a tactical group is analyzed by an artificial neural network and thereby mapped to a small number of characteristic patterns which are called formations. In this way the complex interaction of the players can be reduced to a much easier interaction of the regarding formations. On this first level, analysis is still restricted to frequencies and distributions like coincidences of defence formations of team A against offence formations of team B. Using that information on formation coincidences, frequent pairs of defence-offence-formation can be taken to define the states of the playing process, where then the transitions are defined by changes of those transition-pairs. This approach makes sense, because experience shows that such formation-pairs are normally stable over phases of about 5 seconds.

Now the following question has to be answered: Under which contextual conditions do transitions occur – i.e. what events cause the changes of formation-pairs?

Of course there are a lot of possible reasons. In the SOCCER-project we concentrate on passes because passes change the situation of a match and thus can force the tactical groups to react by changing their formations.

Therefore, on the second level of analysis, the passes are taken from the position data and the frequencies of transitions of the type "formation-pair – pass – formation-pair" are calculated.

The question after collecting this data is whether or not such a transition was tactically successful. I.e. the result of a pass has to be measured in terms of tactics.

Although goals on the one hand with no doubt are the most important and most valuable events in soccer they have one important disadvantage: they are comparably rare and – more or less – stochastically distributed over the sequence of tactical activities.

On the other hand space control seems to be necessary in order to generate pressure and prepare dangerous situations – even if sometimes seemingly harmless long passes can result in unexpected goals.

Therefore, on the third level of analysis, the passes have to be analyzed regarding the space control they generate in the critical areas of the opponent team.

Altogether, these three steps allow for replacing the abstract scheme

"situation i → event + success → situation j"

by the concrete scheme

"formation-pair i → pass + space control → formation-pair j".

In the following, the three analysis steps mentioned above are described in more detail. All results are achieved from the same exemplarily analyzed match.

2 Typing of formations by means of *DyCoN*

Tactical groups like offence or defence form shapes that change depending with situations and interactions. In order to detect tactical behaviour behind those changes it is helpful to reduce the big number of those shapes to a small number of characteristic types or patterns and study their interaction dynamics. Artificial neural networks of type Kohonen Feature Map (KFM) are able to learn types from fed examples, as is shown in figure 1. DyCoN, as an advanced development based on KFM, is able to do so with only a small number of examples and to continue the learning process continuously (KFM, DyCoN: see Perl et al. (2013) and Memmert & Perl (2009)).

More information about net-based soccer analysis can be found in Lees, Barton & Kershaw (2003) and Leser (2006).

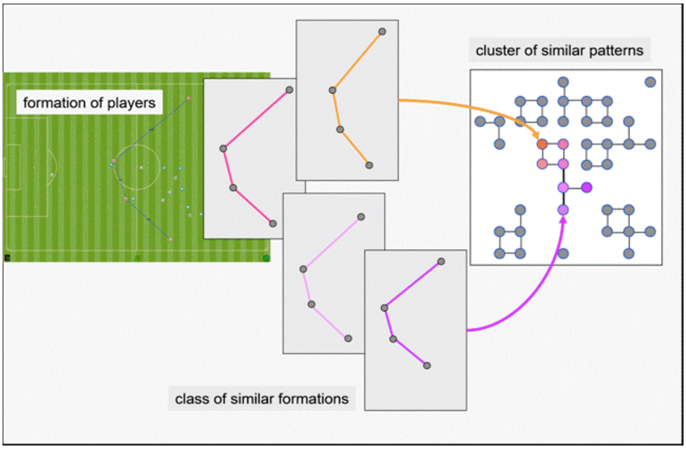

Fig. 1. Typing of formation-patterns by means of artificial neural networks.

The results of that net-based typing are prototypes of formations, which in the following are simply called formations. Some examples can be seen on top of figure 2 together with their frequencies. The matrix on the bottom right gives information about formation-pairs - for example: the pair of defence formation 2 of team A and offence formation 8 of team A has a frequency of 23. On the bottom left one situation of "A2 against B8" is shown on the playing field.

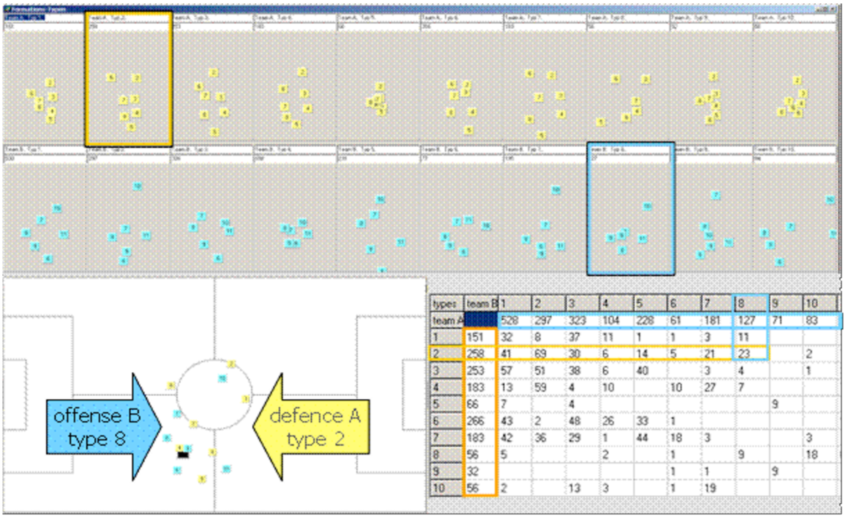

Fig. 2. Examples and coincidences of offence (B) and defence (A) formations.

A formation of one of the teams is not only a reaction on the formation of the other team, but also represents a tactical idea depending on the actual match situation, and therefore the formation is expected to change with the changing situation (also see Perl, Grunz & Memmert (2013)). One important type of situation-changing event obviously is the pass, in particular the long vertical one, directed to the opponent's defence zone. Therefore in the next step the relation between passes and formation-pairs is analyzed.

3 Recognizing the relation between formations and passes by means of SOCCER

One of the components of the game-analysis-tool SOCCER calculates a match protocol based on position data, where in particular passes are recognized. The matrix in figure 3 gives a complete overview on the passes of team B in the context of the related formation-pairs. It shows for example that there was no pass related to formation-pair "A2 against B8" from figure 2. The greatest number of 9 passes is given for the formation-pair "A6 against B5".

	B	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A	163	24	16	17	10	25	4	14	5	2	3	7	6	4	1	4	2	4	2	7	2
1	12	1	4	2	1							1			1	2					
2	1	1																			
3	12	4	1	1		3			1				2								
4	22	2	5		5		2	3	2			2								1	
5	4			2										1							
6	19	2		3		9						2	1				2				
7	20	3	1	5		6	2	2												1	
8	2	1																		1	
9	4							1		1				1				1			
10	6				1			2								2					
11	7		2					1				1								3	
12																					
13	5	1		1		2					1										
14																					
15	7	3		1		1		1													1
16	3	1																			
17																					
18	5	3				1							1								
19	4	2	1					1													
20	2				2																

Fig. 3. Numbers of passes of team B correlated to the formation-pairs.

Based on that information, it can be analyzed how passes change situations – i.e. how a starting formation-pair is transferred to a succeeding formation-pair during the pass.

The matrix in figure 4 shows the pass-correlated situation-changes. Left and on top are the relevant formation-pairs. The entries are the numbers of transitions caused by passes of B.

As an example, the most frequent situation (A6,B5) in 6 of the 9 passes of B stays unchanged, in 2 cases B changes its formation to B1 resp. B3, and in one case A changes its formation to A7.

	A	1	1	2	2	2	3	3	3	3	3	4	4	6	6	6	6	7	7	7	7
A	B	1	3	1	2	3	1	2	3	5	12	2	7	1	3	5	12	1	2	3	5
1	1																				
1	3		1			1															
2	1																				1
2	2																				
2	3																				
3	1						3								1						
3	2							1													
3	3																				
3	5								1	2											
3	12										1						1				
4	2							1		1		1	1								
4	7												2								
6	1						1														
6	3					1									1						
6	5													1	1	6					1
6	12										1										
7	1									1								2			
7	2																		1		
7	3																	1		3	
7	5									1								1	1		3

Fig. 4. Number of transitions between formations-pairs during passes of team B.

Obviously, most of the entries are in the diagonal – meaning that the corresponding passes do not change those formation-pairs. On the first glance it might be confusing that theses passes seem to rarely change the situations. The reason is that the underlying tactical groups are often moving their positions as a whole without changing their players' position relative to each other. With a long vertical pass, for example, the players of the attacking group move vertically towards the opponent's goal without significantly changing the geometric relations between players' positions, while the opponents' defence group is retarding in a similar way.

The chance of getting a goal can be improved by enlarging the pressure in critical areas close to the opponent’s goal. The corresponding activities are passes together with formation changes. Therefore the rate of space control can be taken to measure the success of passes respectively of the corresponding transitions between formation-pairs.

To this aim it is necessary to achieve information about the space control that was generated by the pass and the corresponding changes of players' positions.

4 Voronoi cells as context information and success measure

The Voronoi-cell of a player is the area of all points on the playing field he can reach faster than any other player – under the idealistic assumptions of identical reaction and speed. Nevertheless, if not taken as an individual property but summed up over the players of a tactical group it measures the group's space control rather precisely. In the presented approach two critical areas are in the focus: The penalty-area and the 30-m-area (green vertical line in figure 5) of the opponent's half. At each point in time the percentage rate of space control of the offence group in these areas is calculated by the Voronoi-component of SOCCER. Figure 5 shows an example of a high rate of control, which the blue attacking team has reached in both areas.

More information about Voronoi-cells in sports and soccer can be found in Fonseca et al. (2012) and Kim (2004).

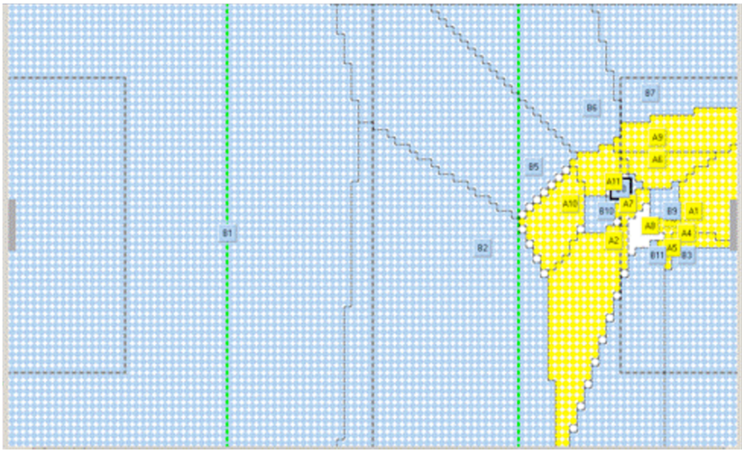

Fig. 5. Space control of attacking team B (blue) against defending team A (yellow).

The rates of space control now can be combined with the corresponding changes of situations, i.e. transitions of formation-pairs, as is shown in figure 6. The transitions with comparably high average rates (>10%) are marked by colours:

Blue colour highlights the cases in which relevant space control is given if the formation-pair is unchanged or the attacking team B changes its formation. Example: (A6,B5) is unchanged or is changed to (A6,B1) or (A6,B3).

Yellow colour highlights the cases in which relevant space control is given if only the defending team A changes its formation. Example: (A6,B3) is changed to (A2,B3).

Violet colour highlights the cases where relevant space control is given if the formation-pair is changed by A as well as by B. Example: (A4,B2) is changed to (A3,B5).

Further it can be seen that two of the blue areas characterize groups of transitions where B varies the response to the defence formations of A.

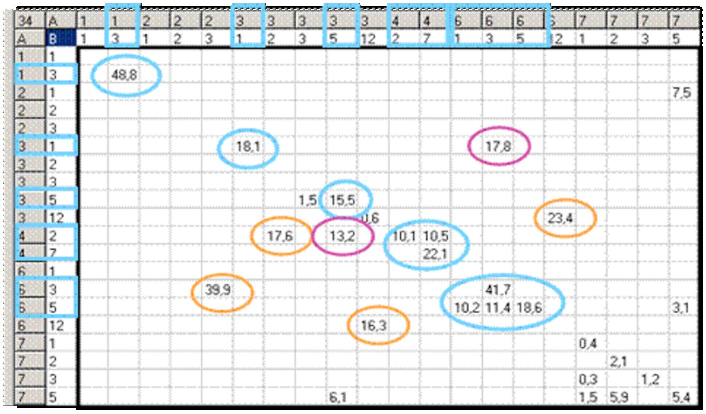

Fig. 6. Average percentage rates of space control caused by passes of team B.

Examples:

Assume B is attacking with formation 5 against formation 6 of defending A. B is playing a pass without changing its formation. The expected resulting space control then is 18.6%. If B would change its formation to 1 or 3 the results were significantly worse with 10.2% and 11.4%.

If, however, B would switch to formation 3 against formation 6 of A, as it did once, it could improve the resulting space control to 41.7%.

This means that the resulting control rate of a pass can be taken as its success indicator and therefore can be taken for tactical planning and/or simulation: Tactical simulation would take those suggestions in order to optimize frequent offence- or defence-processes or to find out which rare and unexpected activities could generate success by surprising the opponent team (Memmert & Perl, 2009).

5 Conclusion

Reducing a complex game to its main patterns and processes can help to analyse its interactions and so improve the understanding of its dynamics and tactical concepts.

Of course, the complex information of 22 players during 2700 seconds per half-time has to be reduced significantly, and therefore the mapping from the real match to the analysis model cannot be correct at every given instance. For example: Mapping the position patterns of tactical groups from 2700 individual situations to only about 20 formation types cannot produce absolute precision. But in turn, much better than the sequence of 2700 situations, it makes visible what the main tactical dynamics is and how successful or unsuccessful processes are.

References

1. Fonseca, S., Milho, J., Travassos, B., & Araujo, D. (2012). Spatial dynamics of team sports exposed by Voronoi diagrams. *Human Movement Science, 31* (6), 1652-1659.
2. Grunz, A., Memmert, D. & Perl, J. (2012). Tactical pattern recognition in soccer games by means of special self-organizing maps. *Human Movement Science, 31*, 334-343.
3. Kim, S. (2004). Vornoi analysis of a soccer game. *Nonlinear Analysis: Modelling and Control, 9* (3), 233-240.
4. Lees, A., Barton, B. and Kerschaw, L. (2003). The use of Kohonen neural network analysis to establish characteristics of technique in soccer kicking. *Journal of Sports Sciences*, *21*, 243-244.
5. Leser, R. (2006). Prozessanalyse im Fußball mittels Neuronaler Netze [Net-based process analysis in soccer], *Human Performance and Sport, 2*, 199-202.
6. Memmert, D. & Perl, J. (2009). Game Creativity Analysis by Means of Neural Networks. *Journal of Sport Science, 27*, 139–149.
7. Perl, J. & Memmert, D. (2011). Net-Based Game Analysis by Means of the Software Tool SOCCER. *International Journal of Computer Science in Sport, 10*, 77-84.
8. Perl, J., Grunz, A. & Memmert, D. (2013). Tactics Analysis in Soccer – An Advanced Approach. *International Journal of Computer Science in Sport, 12*, 1, 33-44.
9. Perl, J., Tilp, M., Baca, A. & Memmert, D. (2013). Neural networks for analysing sports games. T. McGary, P. O'Donoghue and J. Sampaio (eds), *Routledge Handbook of Sports Performance Analysis* (237-247). Abingdon: Routledge.