Report from Dagstuhl Seminar 11271

Computer Science in Sport - Special emphasis: Football

Edited by

Martin Lames[1], Tim McGarry[2], Bernhard Nebel[3], and Karen Roemer[4]

1 **TU München, DE,** martin.lames@sp.tum.de
2 **University of New Brunswick, CA,** tmcgarry@unb.ca
3 **Universität Freiburg, DE,** nebel@informatik.uni-freiburg.de
4 **Michigan Technological University, US,** kroemer@mtu.edu

Abstract

This report documents the program and the outcomes of Dagstuhl Seminar 11271 "Computer Science in Sport - Special emphasis: Football". There were five sessions over the course of three days focusing on separate specific aspects on the relevance, applications and current issues pertaining to computer science in sport. The first session on the first day was about RoboCup – the history, types of games and robots used, and the current topics relevant to machine learning, tracking and planning. The second session on the first day was a miscellaneous session, which looked at broad topics ranging from hardware devices for mobile coaching, uses of positional data in football, rehabilitation methodologies and games for learning. The second day started with a session on modelling sports as dynamical systems combined with the use of neural networks in performance analysis as well as theoretical issues in human movement science. In the afternoon of the second day the session was on topics in computer science specifically relevant to coaches, in which six different people presented. The final day of the conference hosted a session on computer science "behind the scenes" of major sports broadcasters and other media. The sessions were attended by academics, graduate students, coaches, performance analysts and athletes.

Seminar 03.–06. July, 2011 – www.dagstuhl.de/11271

1998 ACM Subject Classification B.4.0 [Input/Output and Data Communications] General, D.0 [Software] General, H.2.8 Database applications, I.2.9 Robotics, I.2.0 [Artificial Intelligence] General, J.0 [Computer Applications] General

Keywords and phrases Sport, Neural networks, Dynamical systems, Robotics, Coaching

Digital Object Identifier 10.4230/DagRep.1.7.1

Edited in cooperation with Peter Lamb

1 Executive Summary

Martin Lames

License Creative Commons BY-NC-ND 3.0 Unported license
© Martin Lames

The Dagstuhl Seminar 11271 "Computer Science in Sport – Special emphasis: Football" stands in a row of 3 seminars introducing the field of computer science in sports. The general aim is to bring experts from computer science together with experts from sports science to explore the options of interdisciplinary work in this exciting field.

An additional aspect was in the focus of this seminar in July, 2011. We invited not only scientists from the field of football research but also practitioners like Max Reckers (NL) who was responsible for computer science at FC Bayern München under coach Van Gaal.

Except where otherwise noted, content of this report is licensed under a Creative Commons BY-NC-ND 3.0 Unported license

This measure led to livelier discussions because the aspects "Does this work in practice?" or "Does practice really need that?" were not only discussed but also given answers from the view of practice.

Another focus was on the pros and cons of technological aids in football. Here, the discussion brought about many issues, being far apart from a totally affirmative standpoint. The reason for the outstanding position of football in European societies is basically founded in its value for entertainment. Each game broadcasted live can be seen as a drama, a ritualized conflict that will produce a result on that very evening that cannot be foreseen in any way. It is this kind of authenticity that gives football its importance. Concerning technical aids we have to be careful that they do not endanger the dramatic properties of the game. So, as in other fields also, it is not wise to do everything we can do.

Finally, the seminar proved again the benefits of the Dagstuhl seminar concept. Experts from different fields that would hardly meet in their normal business had the opportunity to exchange their ideas in many informal meetings. There was positive resonance from most of the participants stressing especially this fact. Several ideas for new projects among the participants were produced and meanwhile initiated. An application for a next seminar on computer science in sports again with an exciting focus will be prepared soon. A "Dagstuhl Manifesto" is going to be published explaining the interdisciplinary perspectives between sports science and computer science in depth.

2 Table of Contents

3 Overview of Talks

3.1 A Survey of the Mobile Coaching System

Arnold Baca (Universität Wien, AT)

License Creative Commons BY-NC-ND 3.0 Unported license
© Arnold Baca
Main reference Baca, A.; Kornfeind, P.; Preuschl, E.; Bichler, S.; Tampier, M.; Novatchkov, H., "A Server-Based Mobile Coaching System," Sensors 2010, 10, 10640-10662.
URL http://www.mdpi.com/1424-8220/10/12/10640/pdf

A wireless system for monitoring, transmitting and processing performance data in sports for the purpose of providing feedback has been developed. Experts are provided with remote data access, analysis and (partly automated) feedback routines. In this way, they are able to provide athletes with individual feedback from remote locations. One specific sport, the system could be utilized for, is football.

3.2 Robot Soccer: A Challenge for AI and Robotics

Sven Behnke (Universität Bonn, DE)

License Creative Commons BY-NC-ND 3.0 Unported license
© Sven Behnke

Robot competitions are a popular way to benchmark robotic systems. They allow for a direct comparison of different approaches to mechatronics, perception, and behavior control outside the own lab at a predefined time. Since 1997, the RoboCup Federation holds annual international competitions for soccer robots in different leagues that investigate different aspects of soccer. While in the simulation league team play and tactics are key, bipedal locomotion, perception of the game situation from a moving camera, and control of complex motions are investigated in the humanoid league.

In my talk, I introduce the humanoid soccer robots of our team NimbRo, which won the tournament multiple times and are currently holder of the Best Humanoid Award. I cover robot construction, visual perception, hierarchical reactive behavior control, and learning.

3.3 Towards Automated Football Analysis: Algorithms and Data Structures

Joachim Gudmundsson (The University of Sydney, AU)

License Creative Commons BY-NC-ND 3.0 Unported license
© Joachim Gudmundsson
Joint work of Gudmundsson, Joachim; Wolle, Thomas

Analysing a football match is without doubt an important task for coaches, clubs and players; and with current technologies more and more match data is collected. For instance, many companies offer the ability to track the position of each player and the ball with high accuracy and high resolution.

Analysing this position data can be very useful. Nowadays, some companies offer products that include simple analyses, such as statistics and basic queries. It is, however, a non-trivial task to perform a more advanced analysis. In our research, we assume that we are given only the position data of all players and the ball with high accuracy and high resolution. We present several tools, for example:

1. Automatically extract (from the position data) a list of certain events that happened during the football match. These events include kick-offs, corner kicks, passes etc. In experiments we could observe that our method is very fast and reaches a high level of correctness. We also learned that errors in the event detection are hard to avoid completely, when looking at only the position data.
2. A tool that aims at analysing a single player's trajectory (the sequence of all positions during a game). More precisely, we look for movements of a player that are repeated often (so called subtrajectory clusters). For example a left wing attacker runs from the centre-line along the left side of the field towards the opponent's goal. And this attacker might repeat this type of movement very often during a game (or perhaps multiple games). Our goal is to detect this kind of frequent movements automatically. Experiments showed that this method is computationally expensive. Nevertheless, it reliably identifies subtrajectory clusters, which then could be used for further analysis.
3. A third example is a tool that evaluates a players passing ability.

This also involves the ability to decide which pass to make i.e., the players overview of the game, ability to receive a pass and to execute a pass. This is joint work with Thomas Wolle.

3.4 Introduction and Discussion of SOMs in Human Movement Science

Peter Lamb (TU München, DE)

License Creative Commons BY-NC-ND 3.0 Unported license
© Peter Lamb
Joint work of Lamb, P.F., Bartlett, R.M., & Robins, A.
Main reference P.F. Lamb, R.M. Bartlett, and A. Robins, "Artificial neural networks for analyzing inter-limb coordination: the golf chip shot," Human Movement Science, 2011, *(in press)*.
URL http://dx.doi.org/10.1016/j.humov.2010.12.006

Kohonen Self-Organizing Maps (SOMs)[1] are a specific type of artificial neural network which, because of the theorized non-linear, self-organizing nature of human movement, appear to represent an attractive method of analysis for such movements[2]. The output of a SOM is commonly visualized as a grid of nodes, each with an associated weight vector.

The dimensionality of the weight vectors is the same as the dimensionality of the input data set. The examples presented in the seminar represent time-series coordination of kinematic joint angles and velocities. An input represents a single time frame, or sample, of a movement pattern and is fed forward to the input layer as an input vector. The dimensionality of the input vectors (and weight vectors) is equal to the number of dependent variables. The number of SOM nodes is typically fewer than the number of inputs, thereby reducing the data and forcing them into clusters of similar data. The steps for training a SOM are summarized as:

1. *Initialization* - Map dimensions, training parameters and initial values for the weight vectors are chosen based on the principal components of the input data set.
2. *Find best-matching node* - For each input vector, the node whose weight vector has the shortest Euclidean distance to the respective input is identified and declared the 'best-matching node'.

3. *Adjust weight vectors* - The weight vectors are adjusted during an iterative training process to model the input distribution. The weight vector of the best-matching node is adjusted the most, while nodes close to the best-matching node (in Euclidean space) are adjusted less, as their proximity decreases. The neighbourhood relation determines the magnitude of these adjustments and is the feature which preserves the topology of the input data set and therefore allows the nodes to self-organize.

Finally, a method for visualizing the nodes is decided upon based on the goals of the analysis. In this case, a 2-D grid on which the nodes form a hexagonal lattice was presented. The U-matrix was demonstrated as a method for visualizing Euclidean distance between neighbouring nodes using a color scale. To enhance the visualization the Euclidean distance can also be plotted on the z-axis so that clusters in the data can be seen more clearly.

On the U-matrix the sequence of best matching nodes which may represent a complete movement pattern can be highlighted with a trajectory. This technique allows high-dimensional changes in coordination between trials and/or testing conditions to be compared.

The concept of training a second SOM using information from the first SOM was also expanded upon. The weight vectors of the consecutive best matching nodes were projected into weight space and the coordinates of the best matching nodes were used as input for the second SOM[3]. Frequently activated regions can be thought of as stable, therefore the visualization represents coordination stability. In technique analysis, the quality of the technique is often judged according to performance outcome[4]. The methods presented here may offer coaches a more objective method for the assessment of sports techniques, one which is based on the movement itself rather than the outcome.

References

1 T. Kohonen. *Self-organizing maps (3rd ed.)*. Springer-Verlag, Berlin, 2001.
2 J.A.S. Kelso. *Dynamic patterns: the self-organization of brain and behavior*. MIT Press, Cambridge, 1995.
3 P.F. Lamb, R.M. Bartlett, and A. Robins, *Artificial neural networks for analyzing inter-limb coordination: the golf chip shot*, Human Movement Science *(in press)* 2011.
4 A. Lees. *Technique analysis in sports: a critical review*, Journal of Sports Sciences **20** 2002, 813–828.

3.5 Tactical Match Analysis In Soccer: New Perspectives?

Koen A.P.M. Lemmink (University of Groningen, NL)

License Creative Commons BY-NC-ND 3.0 Unported license
© Koen A.P.M. Lemmink
Joint work of Lemmink, Koen A.P.M.; Frencken, Wouter G.P.
Main reference W.G.P. Frencken, W.G.P., K. Lemminkab, N. Dellemanc, and C. Visschera, "Oscillations of centroid position and surface area of soccer teams in small-sided games," European Journal of Sports Sciences, 11(4), 215-223, 2011.
URL http://dx.doi.org/10.1080/17461391.2010.499967

Match analysis is the objective recording and examination of behavioural events of one or more players during competition or training. Notational analysis is a method to create a permanent record of the on-the-ball actions of players within a match through hand-based or computerized systems often using video technology. For the analysis of tactical behaviour, large data sets create opportunities for analysing temporal patterns (T-patterns) and network structures. Although these notational systems have improved over time, they still have certain limitations, especially from a tactical point of view. For example, information of position of the actions lack accuracy and, due to a single camera viewpoint, only on- the-ball actions of individual players are monitored properly.

In recent years, technological innovations, such as automated tracking based on video clips and GPS-like technology, have led to new possibilities for match analysis in ball team sports. High-frequency positional player data (up to 1000 Hz) is becoming available in the context of different ball team sports, such as soccer, field hockey, basketball, rugby, and handball.

Until now, these data are typically used to calculate distance, speed and acceleration/deceleration profiles of individual players. These types of analysis do not capture the complexity of a soccer match and new approaches of the game are required.

Data with high spatial and temporal resolution of different players at the same time open up to player vs. player and team vs. team interactions. For example, on individual level it allows for the analysis of symmetry breaking processes in player dyads, whereas on team level attacking and defensive spaces or other geometrical configurations confined by the players can be investigated. It is obvious that the current theoretical frameworks for performance analysis are not suitable for the study of these spatial- temporal game dynamics.

In contrast, dynamical systems theory is a relevant framework and its analytical tools and methods are ideal because they can cope with this type of data. This approach leads to new insights into the interactions of players and teams within different ball team sports. New ideas and research findings on several geometrical configurations in small-sided games and real matches in elite soccer will be presented to expand the existing knowledge in this area.

3.6 Position Tracking as Current Challenge in Game Sports Analysis

Roland Leser (Universität Wien, AT)

License Creative Commons BY-NC-ND 3.0 Unported license
© Roland Leser

About 10 to 15 years ago only top level teams used computer assisted video annotation systems to analyze sport games and training sessions. The progress in hardware and software development made it happen that nowadays this technique is used even at amateur level. Pointing to another analysis technique we have at present similar conditions than in the situation described above. Very expensive video based position tracking systems are used by few of the top teams worldwide to analyze their game play and GPS-systems are applied to analyze training sessions of outdoor sports. Radio wave based tracking systems are currently not wide spread for performance analysis but they could dominate the future. By tendency radio wave sensors become smaller and cheaper in the next years and radio wave based tracking systems are much less service intensive than other systems. Looking forward, this kind of tracking system could be a worthwhile alternative to analyze games and training sessions of game sports for many teams. This presentation gives an overlook on the preparatory work of installing an industrial radio wave based tracking system (www.ubisense.net) for game sports analyses, outlines current results and looks ahead to future works.

3.7 The Game Data Project in the Fußball Bundesliga

Daniel Link (TU München, DE)

License Creative Commons BY-NC-ND 3.0 Unported license
© Daniel Link

The German Soccer League (called in German Fussball Bundesliga) is a respectable social and economic factor in Germany. The income of Fussball Bundesliga in the season 2010/11 includes more than 1 billion €from advertising and TV rights, but at the moment no commercializing of game related data takes place. To improve this situation the Game Data Project was started in order to develop a Game Data Library for storing and delivery of basic match data, tracking data (at 25 Hz) and event data. This data is used to create statistics for Fussball Bundesliga clubs, online media, TV and betting companies.

The data collection includes three basic processes. In the live process two live observers in real time within a stadium telephone are connected to two live typists, which enter the data into the database. In a near real time process two video observers who verify data are involved in a control center away from the stadium. The tracking is done by a two camera system at the stadium, where an observer is able to make manual correction to data.

The observation of events bases on a Game Data Model, which does required operational clarity. This ontology bases on object orientation and provides a data structure for the efficient processing and storing of data and the smart calculation of statistics. The challenges for the scientific discipline sport informatics in the context of the Game Data Library are to use the enormous amounts of data that will be generated in future and to develop methods and tools and to analyze it.

3.8 Performance at the FIFA Women's World Cup 2011

Keith Lyons (University of Canberra, AU)

License Creative Commons BY-NC-ND 3.0 Unported license
© Keith Lyons

This paper presents data from the games ($n = 16$) in the first two rounds of the 2011 FIFA Women's World Cup. Attention is drawn to patterns of goal scoring and the relationship with FIFA ranking (18 March 2011). The paper includes a profile of winning, losing and drawing in the 16 games (presented as averages). The paper is used as a stimulus paper for discussion of technical and tactical aspects of game play at this World Cup and in football generally. The presentation makes use of Prezi to share these data.

http://prezi.com/21c82yn9orcj/winning-performance-at-the-2011-fifa-womens-world-cup/

3.9 Human Information Processing: The Penalty Kick and Direct Free-kick in Football

Tim McGarry (University of New Brunswick, CA)

License Creative Commons BY-NC-ND 3.0 Unported license
© Tim McGarry

This preliminary investigation considers information processing constraints placed on the goalkeeper in football when defending a penalty kick or direct free-kick. Statistics from the 1976–2008 European Championships and 1978–2010 World Cups affirm the importance of the penalty kick, including penalty shoot-outs in knock-out competition, for determining winning outcomes. Of note, the fourth-placed penalty taker in penalty shoot-outs was reported to be much less successful, for whatever reason, than other penalty takers in the line sequence. The data yielded 0.81, 0.77, 0.79, 0.54 and 0.75 scoring probabilities for the first through fifth placed penalty takers, respectively.

These findings on penalty kicks confirm anecdotal knowledge regarding goalkeeper disadvantage, attributed primarily to unyielding time constraint for decision-making and movement execution. For a direct free-kick, the time constraint on information processing imposed on the goalkeeper is lessened because of increased time afforded by longer ball flight. The use of a defending wall of players also assists the goalkeeper. First, the wall presents an obstacle to goal for the attacking player taking the free-kick, thus reducing the chances of goal threat from the direct shot, and, second, it reduces the "open" goal area that the goalkeeper will assign priority to protecting. The suggestion offered here is that the defending wall disadvantages the goalkeeper on those times that the ball defeats (passes) the wall on way to the goal area that the wall is designed to protect. In these instances, the goalkeeper is presented with late visual information that provides insufficient time for generating an appropriate response. Statistics from the 2004 European Championship and 2002–2006 World Cups reported general scoring probabilities of 0.08 for direct free-kicks, with increased probabilities approaching 0.11 for free-kicks taken from a central location in front of goal. Moreover, similar time constraints on goalkeepers were observed in these instances as for penalty kicks, assuming the aforementioned premise of late information pick-up holds. Further research on the use of a defending wall as a means of defending direct free-kicks in football is required.

3.10 “Empirical Coaching”: Guiding Principles in Enabling Coach Expertise

Stuart Morgan (Australian Institute of Sport, Bruce, AU)

License Creative Commons BY-NC-ND 3.0 Unported license
© Stuart Morgan

Successful football coach, Bernd Schröder, once said “there is no science in football”. Performance analysis and computer science in sport has made considerable progress in recent years, yet Schröder’s statement remains representative of the perceptions of many coaches. Furthermore, 2008 Tour de France winner Carlos Sastre, complained about the counter-intuitive nature of his cycling power software, and said “The computer must understand me. I don’t understand the computer. It is more intelligent than me…”. These two quotes illustrate two of the most significant questions for computer science in sport: what are the barriers that prevent coaches from embracing sports and computer science, and, how can data be presented in more meaningful ways such that coach expertise is enabled (rather than threatened) by science?

It is proposed that coaches develop expertise using primary modes of game feedback, such as direct visual observation, video review, basic game statistics, input from other first hand observers such as assistant coaches, and crude insights from match outcomes such as the progressive scoreline. It is from these non-empirical sources that coaches build and test decision making schemas. Certainly, it is not until much later in their careers that coaches become exposed to empirical data, often derived by specialist sports scientists, who provide the them with a potentially bewildering array of game and performance data. It may often be that coaches do not possess the knowledge frameworks to absorb or exploit these sources of information, and that empirical data presented by scientists does not therefore influence their coaching decisions. It is proposed that consideration needs to be given to the problem of data visualisation, and in particular, matching data presentation techniques to the learning styles, decision making schemas, and game perception frameworks that coaches have otherwise used throughout their careers.

This presentation aimed to open discussions about how performance analysis data can be visualised using advances in computer science in ways that enable and amplify coach expertise, rather than attempting to supplant it. An exemplar was presented in which frequent itemsets were used to scan large amounts of ball movement data in field hockey for recurring ball movement trends. Visualisation techniques were presented, for which the primary aim was to communicate a simple pattern from within large and complex datasets.

3.11 Net-based Game Analysis by Means of DyCoN and SOCCER

Jürgen Perl (Mainz, DE)

License Creative Commons BY-NC-ND 3.0 Unported license
© Jürgen Perl
Joint work of Perl, Jürgen; Memmert, Daniel; Grunz, Andreas

Game analysis has become much easier by automatic position recording. However, the problem remains how to transfer the astronomic amount of available data to a selection of useful information. Our approach is based on two ideas: data reduction and pattern recognition.

In the first step, by means of SOCCER, the position data of the players of a team are reduced to those of tactical groups like offense or defence, followed by normalization, where the players' constellations on the playground are reduced to their geometric formations relative to their centroids - i.e. the playground-independent position patterns.

In the second step, those patterns are learned by the self-organizing neural network DyCoN, resulting in a collection of formation clusters, each containing a variety of shapes of the corresponding formation type. Based on that information, game analysis with DyCoN and SOCCER works as follows: Along the time-axis, position data of interacting tactical groups are fed to the net, which recognizes the time-dependent corresponding formation types.

A first quantitative analysis then results in frequency distributions of formation types. Recombination with the playground position information leads to a playground specific frequency distribution. And adding the time information finally allows for process and interaction oriented analyses. Moreover, SOCCER not only offers quantitative results but also qualitative ones like game animation and tactical analyses by use of additional semantic action valuation. While DyCoN and SOCCER are developed by the author, data preparation and semantic analysis are supported by the program VisuCat, developed by Andreas Grunz [1, 4].

The project as a whole is run in co-operation with Daniel Memmert [2, 3], German Sports University Cologne, and his game analysis working group.

References

1 A. Grunz, D. Memmert, and J. Perl, *Analysis and simulation of actions in games by means of special self-organizing maps*, International Journal of Computer Science in Sport **8** 2009, 22–37.

2 D. Memmert, and J. Perl, *Game creativity analysis by means of neural networks*, Journal of Sports Sciences **27** 2009a, 139–149.

3 D. Memmert, and J. Perl, *Analysis and simulation of creativity learning by means of artificial neural networks*, Human Movement Science **28** 2009b, 262–282.

4 A. Grunz, S. Endler, D. Memmert, and J. Perl, *Netz-gestützte Konstellations-Analyse im Fußball [Net-based constellation analysis in soccer]*. Workshop on Computer Science in Sport, Darmstadt, 2011 (to appear).

3.12 Can We Measure Football Tactical Behavior by Using Dynamic Positional Data?

Jaime Sampaio (Universidade de Trás-os-Montes – Vila Real, PT)

License Creative Commons BY-NC-ND 3.0 Unported license
© Jaime Sampaio

Football can be considered as a game sport comprised of subsystems with intra and inter-dynamic interactions and that the findings of chance and chaos in the course of the game are to be expected within the framework of these dynamical (complex) systems. The present study explored how football players' positional data can be used to access tactical behavior by measuring movement patterns and inter-player coordination. A pre post-test design was used to access the effects of a 13-week constructivist teaching program by accomplishing a 6×6 football small-sided game, played on a 60×40 m outdoor natural turf pitch. Data was captured at 5Hz by GPS devices (SPI Pro, GPSports, Canberra, Australia). In addition to positional data gathered (x, y) the following dependent variables were calculated in this study: distance of player from the geometric center of the team; maximal and minimal distance of player to the geometric center of the team. All data was analyzed with non-linear signal processing methods such as Approximate Entropy and Relative Phase. Approximate entropy values were lower in post-test situations suggesting that these time series became more regular with increasing expertise in football. Relative phase post-test values showed several stability periods with a clear trend to moving in anti-phase, as measured by players' distance to the center of the team.

Players' maximal and minimal distance from the center of the team had smoother variations, but more regular values were found in post-test and decreases in distance of 0.83 m and 1.5 m, respectively. It seems possible to measure Football tactical behavior by using dynamic positional data. Advances in this topic should allow exploring different variables, different samples and also the positional relations between confronting teams, opening up new topics under the tactical scope, allowing to narrowing the gap between science and coaching.

3.13 Model-Based Optimization of Pacing Strategies for Cycling Time Trials

Dietmar Saupe (Universität Konstanz, DE)

License Creative Commons BY-NC-ND 3.0 Unported license
© Dietmar Saupe

Based on a physical model for the forces that must be applied by pedaling while cycling and a simple physiological model for the exertion of the athlete as a function of his/her accumulated power output, an optimal riding strategy for time trials on mountain ascents is computed. A combination of the two models leads to a mathematical optimization problem that can be solved numerically by discretization. The physical model depends most sensitively on an accurate estimation of the road slope on the course. For this purpose, we also present a new method that combines model-based slope estimations with noisy measurements from multiple GPS signals of differing quality. Altogether, we provide a means to analyze rider performance, to identify and quantify potential performance improvement, as well as to instruct the athlete exactly where and how to change his/her pacing strategy to achieve these gains.

3.14 Evaluation of Image Detection Systems in Football

Malte Siegle (TU München, DE)

License Creative Commons BY-NC-ND 3.0 Unported license
© Malte Siegle

In football there are several position detection systems providing x, y-coordinates and movement velocities of all players on the pitch (e.g. AMISCO). These data are used to analyse different aspects of football, for example the loads imposed on players or fatigue during a match. Undoubtedly, coaches as well as scientists have a huge interest and benefit of these analyses. Nevertheless, the quality, especially the accuracy of the position detection systems should be controlled. There are only a few studies analysing the accuracy of different position detection systems, but these studies show either problems in their test design, or used lighting gates, resulting in a single comparable value for each test run. The current study presents a new method of analysing accuracy of such data. Using a Laveg laser measurement device, positions of two runners were obtained by the empirical gold standard and by a two camera based position detection system. By using the Laveg device, huge numbers (150-300) of comparable values could be obtained for every single run. Different tests (Linear runs, Acceleration-Stop-Turn-Acceleration-Runs, and different distances of runners to cameras) were performed in order to detect possible error sources of the system. Main problems for the system occurred for runners further away from the cameras and for players overlapping each other. Linear runs were measured accurately. Altogether, the presented method raises the standards of controlling the accuracy of position detection systems. Future studies should focus on the separation of different error sources.

3.15 Game Interruptions in Football

Malte Siegle (TU München, DE)

License Creative Commons BY-NC-ND 3.0 Unported license
© Malte Siegle

The objectives of the study were to analyse game interruptions of league soccer in detail and the tactical use of game interruptions. Sixteen matches of a German first league soccer team were observed. An observational system was designed to assess interruption types, score, duration of interruption, location of interruption, time of interruption and number of occurrences. Results showed that there is an average of 108 interruptions per match. Throw-ins and free kicks were most frequent. Referee balls, penalties, and injuries occurred least often. In 38% of the total time matches were halted. The analysis showed significant differences concerning the influence of the location of interruption, score, and time of interruption on the duration of different interruption types ($p < .05$).

The results of the study showed the tactical use of game interruptions during league soccer matches, e.g. goal kicks of the leading team take longer towards the end of the match. Moreover, analysis of positional data showed that relative running distances during interrupted match intervals were reduced by 1 m/s compared to those during running match intervals. Examining game interruptions has turned out to be a valuable source of information adding to our knowledge on soccer. We have shown evidence that the durations of many interruptions serve tactical purposes, a well-known hypothesis in practice.

3.16 Working with the Austrian U17 Women's National Football Team

Johannes Uhlig (Universität Wien, AT)

License Creative Commons BY-NC-ND 3.0 Unported license
© Johannes Uhlig

The focus of the article discusses the work with the Austrian U17 women's national football team. It mainly illuminates the strategic and tactical work and game philosophy and the basic 4-4-2-system gets explained in more detail. This 4-4-2-system changes in attack in a 4-2-4-system and in the defence in a 4-5-1, whether the switching phases often decides games.

The match schedule is mentioned as a special intervention, which is geared more closely to the respective adversaries. Finally, the theoretical and practical work with the TAP (Tactical animation program) is presented.

3.17 Offside and Wembley Goal – Can Computer Science Help Overcome Erroneous Decisions in Soccer?

Josef Wiemeyer (TU Darmstadt, DE)

License Creative Commons BY-NC-ND 3.0 Unported license
© Josef Wiemeyer

The field of sport practice is full of interesting phenomena that lead to uncertainties and sometimes annoyance. Sport science is able to uncover the reasons for these phenomena and to develop solutions. Two phenomena in soccer are a persistent threat to fairness und equal chances in soccer:

1. Erroneous offside decisions (Reasons: perspective and synchronous visual perception, flash-lag effect) according to research about 20 to 25% of offside decisions are wrong!
2. Erroneous goal decisions (Reason: depth perception and stereoscopic vision)

Using these two examples the question arises if and how computer science can help to improve the situations of the referees in soccer. In the past, selected options have been suggested to solve these problems. This statement emphasizes the strong support computer science in sport can give to solve persistent issues in soccer practice. Referees and their assistants are systematically overloaded by the perceptual demands in offside and goal decision situations. Information technologies should support them to ensure a maximum level of fairness and equal chances.

4 Working Groups

4.1 Session Summary: RoboCup

Keith Lyons (University of Canberra, AU)

License Creative Commons BY-NC-ND 3.0 Unported license
© Keith Lyons

The second session on Day 1 of the Computer Science in Sport Conference (Special Emphasis:Football) at Schloss Dagstuhl was dedicated to Robocup. Sven Behnke (Universität Bonn) introduced the session with some historical background about Robocup competitions. Bernhard Nebel (University of Freiburg) provided further background about the origins of Robocup. He discussed sensor interpretation (inputs and outputs) and noted the importance of cooperative sensing. Bernhard explored the ways in which robots can act cooperatively:

1. Avoidance of interference
2. Task decomposition and re-allocation
3. Joint execution
4. Dynamic role re-assignment

There are four roles for each robot in 4v4 Robocup: goalkeeper (fixed), active player, supporter, and strategic. Each role has a preferred location that is situation dependent. Each player computes the utility for each outfield role and shares it with the other outfield robots.

Bernhard discussed the development of table soccer as a micro-version of large space games. There is a commercially available table. This table uses a reactive scheme but Bernhard has been looking at anticipation schemes with decision theoretic planning. Recent research has simulated games between a decision theoretic system against a reactive system.

Sven and Berhard's presentations stimulated a great deal of interest and questions. Sven concluded the session with a discussion of technical challenges in humanoid robot design and performance.

4.2 Session Summary: Miscellaneous

Keith Lyons (University of Canberra, AU)

License Creative Commons BY-NC-ND 3.0 Unported license
© Keith Lyons

The Computer Science in Sport Conference (Special Emphasis:Football) at Schloss Dagstuhl had a mixed group of presentations in the third session of Day 1. Malte Siegle was the first presenter in the session and discussed his work with Martin Lames on Game Interruptions in football – a neglected element for modelling the demands if the game. Malte introduced his paper with a consideration of the use of position detection systems to measure performance in football. He noted that these systems provide no data about game interruptions. In his presentation he shared an analysis of 1729 interruptions in 16 matches and discussed the time, type, location and duration these interruptions. He used Amisco System data to provide more detail about player performance in these games. Malte noted that interruptions in play were not as long as ball in play. These interruptions were located between intermittent bouts of high intensity match time (most of which were not more than a minute in length before the next interruption). He noted that:

1. There was an average of 108 interruptions per match: these ranged from 0.13% (penalties) to throw in at 39.69% of all interruptions.
2. The average duration of these interruptions ranged from a throw in at 9 seconds to injury at 82.5 seconds.

Malte then made some very important observations about how the place where the interruption takes place affects the length of interruption. He provided some interesting data comparing attacking and defending throw ins. He noted too that direct free kicks in offensive areas with a direct shot at goal opportunity take longer and can reach an average of 36.59 seconds. Malte indicated that the state of play (winning, losing, drawing) has an impact of the length of interruptions. A team winning can take up an additional 3 seconds on goal kicks and up to 5 seconds on free kicks. This tendency for winning teams to take longer over interruptions becomes even more noticeable towards the end of the game (particularly in relation to throw ins). Malte concluded his presentation with data about distance travelled in uninterrupted and interrupted games. He used Amisco data to provide detail of these distances. Malte noted that there was evidence that goalkeepers run more in interrupted play and central defenders less. Malte's final point was an invitation to consider how interruptions might be used for player recovery and that this recovery may vary within a team depending on a player's positional responsibilities. Malte's and Martin's work has received recent publicity [1, 2].

The second presentation of the session was made by Josef Wiemeyer and was titled Offside and the Wembley Goal – Or can Computer Science help overcome erroneous decisions in Soccer? In his presentation, Josef noted:

1. 20–25% offside decisions are wrong.
2. 80% of these are false alarms
3. Decisions about offside are affected by synchronous optic perception [3, 4].

Josef indicated the role training of synchronous optic perception can play in improving decision making. However there is no evidence of the longer term affects of this training (experimental trials last six weeks) and there is still the issue of dealing with moving stimuli [5] and the Hazelhoff flash lag effect [4]. Josef discussed three solutions to these problems:

training, technology, and changing the rules. Josef then extended his discussion to the arbitration of goal line technology and used examples of 'goals' from 1966 and 2010 (Germany v England). He provided details of FIFA and IFAB discussions around goal line technology. He concluded his presentation with an invitation to delegates to consider transparency, justice and fairness in decision making by officials.

Karen Roemer presented the third paper of this session and invited delegates to discuss the design options for a longitudinal study of female athletes' ACL injuries (including female football, basketball and volleyball players). Karen noted that most research into ACL injury is mostly retrospective. She is keen to plan a prospective study.

Arnold Baca (Universität Wien) followed Karen's presentation with a discussion of the development of a mobile coaching system (Mobile Coach 1.0). Arnold noted the feedback potential of this system for elite and mass participation applications. Two papers detail the development of this work [6, 7].

Josef Wiemeyer concluded the session with a discussion of Serious Games New options for learning and training in sport. He discussed the role serious games can play in health promotion and their growing use in *exergaming*. He sounded a note of caution about the energy expenditure in such games and discussed the relative small transfer of skills from games to real life sport. He concluded that "games support what they demand". He encouraged delegates to consider the role serious games can play in improving: sensory motor activity; cognition; motivation, emotion, volition; social competency; and media competency. The session concluded at 6 p.m.

References

1 M. Pangallo. *Men are 'drama queens' when it comes to football, say scientists.* `http://www.metro.co.uk/sport/oddballs/868049-men-are-drama-queens-when-it-comes-to-football-say-scientists`, 1st July, 2011.

2 Inside World Soccer. *Men footballers play act more than women do, say scientists.* `http://www.insideworldsoccer.com/2011/07/men-footballers-play-act-more-than.html`, 2nd July, 2011.

3 M. Sachsenweger. *Testing visual perception of three-dimensionally moving objects (dynamic stereoscopy).* Documenta Ophthalmologica **64** 1986, 379–385.

4 M. Baldo, R. Ranvaud, E. Morya. *Flag errors in soccer games: the flash-lag effect brought to real life.* Perception **31** 2002, 1205–1210.

5 R.R.D. Oudejans, R. Verheijen, F.C. Bakker, J.C. Gerrits, M. Steinbrückner, and P. J. Beek. *Errors in judging 'offside' in football.* Nature **404** 2000, 33.

6 A. Baca, P. Dabnichki, M. Heller, and P. Kornfeind. *Ubiquitous computing in sports: A review and analysis.* Journal of Sports Sciences **12** 2009, 1335–1346.

7 A. Baca, P. Kornfeind, E. Preuschl, S. Bichler, M. Tampier, and H. Novatchkov. *A Server-Based Mobile Coaching System.* Sensors **10** 2010, 10640–10662

4.3 Session Summary: Dynamical Systems and Neural Networks

Jürgen Perl (Mainz, DE)

License Creative Commons BY-NC-ND 3.0 Unported license
© Jürgen Perl

The idea of the session was to demonstrate how the complex dynamics of systems - as e.g. are endurance of athletes, phases of team positions on the playground, or interactions of tactical groups - can be analyzed by means of appropriate modelling. There are mainly two approaches that support each other but can be dealt with separately, as had been done in the session: The dynamics of a system or a team as a whole and the behavioural patterns of specific functional or tactical groups.

In the first part of the session, Dietmar Saupe from the University of Konstanz, Germany, started with an introduction to the ideas of Dynamical Systems from a mathematical point of view, where an iteratively described process moves through phase spaces and eventually finds an attracting fix-point - or is lost in the chaos of an infinitely dense set of attractors. Those system properties can be mapped to changing phases as well as to aspects of stability and instability in motions, endurance sports, or games. His example of application came from the area of endurance sports, where the biker together with the bike and the environment like road surface, altitude profile or weather conditions build a complex dynamical system, which can be modelled and analysed by means of biomechanical equations.

In the second presentation, Jaime Sampaio from the University of Vila Real, Portugal, continued with position analysis in small sided (6 vs 6) soccer, where the success of the teams depends on the relative positions of the players. Subjects of the study were dynamical systems behaviour of the group like the effect of changes in single players' positions on tactical results, stability periods and relative phase analyses. Moreover, the connection to net-based pattern recognition techniques became clear.

The third presentation was given by Koen Lemmink form the University of Groningen, Netherlands, who also dealt with small sided soccer, concentrating on phase analyses: The centroids of the players' position build abstract team positions that move over the playground and so build time-dependent dynamical patterns. Sometimes the patterns of the both teams are in phase, sometimes not. The question of those phase-oriented analyses is in which way in-phase and anti-phase behaviour contain information about the tactical orientation and success of a team.

The second part of the session started with an introduction to self-organizing neural networks, given by Peter Lamb from the Technical University of Munich, Germany, who demonstrated how those nets are organized, how neurons can learn, and how such networks can be applied to analyse time-series data. His main example dealt with motions in golf, where networks can be used for identifying changes in coordination, clustering motion patterns and visualization of stability, which is also specific to dynamical systems and so focuses on the connection between dynamical systems and neural networks.

In the last presentation, Jürgen Perl, Mainz, Germany, demonstrated how self-organizing neural networks can be used for analyzing tactical behaviour in soccer games. To this aim, the constellations of tactical groups relative to their centroids are normalized to formations, the patterns of which can be learned and clustered to specific types by means of neural networks. The time-series of those types together with the corresponding centroid information build the basis for quantitative as well as for qualitative game analysis.

4.4 Session Summary: Coaching

Stuart Morgan (Australian Institute of Sport, Bruce, AU)

License Creative Commons BY-NC-ND 3.0 Unported license
© Stuart Morgan

Session 3 of Day 2 at the Computer Science in Sport Conference (Special Emphasis:Football) at Schloss Dagstuhl was dedicated to Coaching themes. The session was chaired by and introduced by Dr Stuart Morgan (Australian Institute of Sport). His introduction focused on the challenges and important issues in the communication between coaches and scientists in high performance. The presentation also explored the idea that a major contribution of data analytics and computer science in sport is in addressing the "signal to noise" problem where important patterns within a dataset may be obscured within very large amounts of data. An example of this challenge was presented using ball movement data from the 2010 Champions' Trophy Tournament, and one useful solution using association mining techniques to reveal frequent pattern itemsets was presented using these data. The presentation concluded by proposing that two significant challenges were current in computer science in sport:

1. to identify the barriers that prevent coaches from embracing sports and computer science;
2. to explore new ways that data be presented such that existing coaching expertise is *enhanced* by emprically-derived information.

The next presenter was Professor Keith Lyons (University of Canberra, Australia), who used the online presentation system, Prezi, to share data from the first two rounds (n =16 games) of the 2011 FIFA Women's World Cup. Professor Lyons drew attention to patterns of goal scoring and the relationship with FIFA ranking (18 March 2011). The paper included a profile of winning, losing and drawing in the 16 games (presented as averages). The paper was used as a stimulus for a discussion of technical and tactical aspects of game play at this World Cup and in football generally.

Associate Professor Tim McGarry (University of New Brunswick, Canada) then presented a discussion paper titled: "Human Information Processing: Penalty and Free Kicks". Dr McGarry shared some descriptive data from penalty kicks and shoot outs from European Championships and World Cups from 1976 to 2010 (1976 saw introduction of penalty shoot outs). He noted that in penalty shoot outs, penalty number 4 appears to be the weakest link in a shoot-out (of 5 penalties taken). Dr McGarry posed the question about who should take this penalty? Should the most experienced (and successful) penalty taker be allocated this role? Dr McGarry discussed goalkeeper actions in penalties and considered the options available in the time frame of the penalty kick task (approximately 400 ms). Dr McGarry also discussed free kicks, and presented descriptive data from the 2002 and 2006 World Cups, and the 2004 European Championships. He discussed the optimisation of goalkeeper reaction and response, and the role of a defensive wall in these free kick situations.

Dr Joachim Gudmundsson (NICTA, Australia), was the fourth presenter in this session. He discussed extracting and making sense of information from trajectories. He discussed his work in the defence services, with animal behaviour and in sport. Dr Gudmundsson presented visualisations depicting player movements and possible ball passing options in football data.

Dr Johaness Uhlig (Universitat Wien) was the next presenter and discussed his work with the Austrian Under 17 Women's team and with his club team. He described his coaching and his tactical approach based on a basic 4-4-2 formation. Dr Uhlig emphasised three phases of play: attack, defence, switchover. He discussed the development of a tactical animation program (TAP) to support coaches and its use in practice.

In the final presentation for the session Dr Koen Lemmink (University of Groningen) on Tactical Match Analysis in Soccer: New Perspectives? For some of the ideas discussed in this paper see Frencken, Lemmink and Delleman (2010). Dr Lemmink explored three different approaches to observing and analysing performance. He provided examples of each approach. Firstly, a "Practice Model" that uses frequencies of event data and player profiles. This is coach driven and has a focus on direct feedback. Next, a "Statistics Model" that identifies performance indicators, and notes statistical differences. This is a domain populated by mathematicians, statisticians and econometricians, with a focus on pattern analysis and recognition. Finally, a "Theory Model" that uses scientific insight to understand interactions and networks. He emphasised the possibilities of building multidisciplinary teams that had a strong focus on explanations and shared rich data on positional play.

A vibrant discussion followed the presentations, that was particularly relevant to the high performance sports domain. Max Reckers, formerly the performance analysis specialist at the Bayern Munich Football Club, provided considerable insight to the discussion, and he discussed his ideas about sharing data. This included consideration of the role of the embedded scientist in a sport setting.

4.5 Session Summary: Media and Data Acquisition

Keith Lyons (University of Canberra, AU)

License Creative Commons BY-NC-ND 3.0 Unported license
© Keith Lyons

The morning session discussed Media and Data Acquisition issues. The session was chaired by Daniel Link (TU München). Daniel presented first in this session. He reported on the Game Data Library Project for the Bundesliga. Daniel discussed the game observation process for the Game Data Library. This involves the acquisition of basic data that includes match information data, tracking data (at 25 Hz), event data, static video data that are used to create raw data and statistics. Daniel presented the architecture of this service to provide data flow. He discussed the Game Data Model. Daniel presented an ontology of definitions in use in this project. This ontology has a data structure for: smart calculation; efficient processing and storing of data; and object orientation and the use of Unified Modelling Language (UML). Daniel concluded his talk with a consideration of the challenges of this project for sport science. These included how to use the enormous amounts of data that will be generated and how to develop tools to analyse the data.

Roland Leser (Universitat Wien) was the second presenter in the session. His topic was Position tracking as a challenge in game sport analysis. In his talk Roland gave an excellent exposition of how to develop a position tracking system. He noted systems such as Tracab and Catapult. He discussed radio wave systems too, including Ubisense (tag) and InMotio LPM (transponder). In choosing a system for use in his research Roland identified these criteria:

1. Off the shelf availability
2. Price
3. Sensor size
4. Sampling rate
5. Accuracy
6. Robustness (hardware, signal, definition of player)
7. Application in training and game play
8. Opponent agreement within competition

Roland discussed the use of an Ubisense system. To date this system has not been used extensively in sport. He demonstrated the installation of the system in a sports hall. Ubisense has a 160 Hz facility that is not common with other Ubisense clients. The hall is calibrated and then checked for accuracy of measurement. The system allows some for data filtering (low pass and Kalman). Roland noted the development of software tools for the system to enable data visualisation (including heat maps) and performance analysis. Roland shared an example of the recording movement with the system (small sided football).

The final presentation of the morning was by Malte Siegle. Malte looked at the accuracy of image recognition in dynamic situations. He shared the development of protocols to check the accuracy of image recognition in respect of Laveg and laser light measurement. The field tests were conducted in a soccer stadium:

1. A linear run near the cameras with constant velocity. (Image detection worked well.)
2. Acceleration, stop, reacceleration in same direction. (Image detection issues arise with up to 1 metre error.)
3. Two players move towards each other and return after 180 degrees turn. (An error of more than 1.5 metres.)
4. Circular run with constant velocity (Image detection worked well.)

Malte noted the variability in errors in these tests and discussed the impact of the player's distance from the cameras. These tests had identified the need for better static position detection and the clear differentiation of error sources (distractions). Malte did end with some very positive views about the protocols: good values were recorded and problems were identified. This research raised the possibilities of a new standard in the evaluation of image detection. Ultimately this will lead to the comparisons of different image detection systems.

Participants

- Arnold Baca
Universität Wien, AT
- Zied Bahrouni
TU München, DE
- Sven Behnke
Universität Bonn, DE
- Joachim Gudmundsson
The University of Sydney, AU
- Peter Lamb
TU München, DE
- Martin Lames
TU München, DE
- Koen A.P.M. Lemmink
University of Groningen, NL
- Roland Leser
Universität Wien, AT
- Daniel Link
TU München, DE
- Keith Lyons
University of Canberra, AU
- Tim McGarry
University of New Brunswick, CA
- Stuart Morgan
Australian Institute of Sport, Bruce, AU
- Bernhard Nebel
Universität Freiburg, DE
- Jürgen Perl
Mainz, DE
- Max Reckers
Amsterdam, NL
- Karen Roemer
Michigan Technological University, US
- Jaime Sampaio
Universidade de Trás-os-Montes – Vila Real, PT
- Dietmar Saupe
Universität Konstanz, DE
- Malte Siegle
TU München, DE
- Otto Spaniol
RWTH Aachen, DE
- Johannes Uhlig
Universität Wien, AT
- Josef Wiemeyer
TU Darmstadt, DE