# Motion and Episode Models for (Simulated) Football Games: Acquisition, Representation, and Use

Michael Beetz, Thomas Stammeier, and Sven Flossmann

*Informatik IX, Technische Universität München*
*beetz@in.tum.de*

## Abstract

*One of the key problems in the study of multi agent systems in which the agents exhibit continuous behavior is the automatic recognition and analysis of intentional activities based on observable behavior. Such an analysis requires software systems to structure motions into episodes that are meaningful in the application domains, to acquire and maintain models of the activities, and to use such models to reason about multi agent system behavior. In the research sketched in this paper we study the acquisition of episode and motion models for football games. We show that these models allow for the realization of impressive application systems including interactive football TV and agent systems that assist coaches in analyzing their teams.*

## 1. Overview

Football games considered as multi agent systems are excellent example applications for the automated recognition and analysis of agent activities based on observable behavior. The automated analysis of football games requires integrated computer and sensor systems that are capable of (1) acquiring position and motion data of the players and the ball, (2) interpreting these data in terms of intentional activities, such as dribblings and passes, and (3) assessing the game based on an inferred abstract game model.

The research reported in this paper is part of an ambitious, mid-term project that studies the automated analysis of football games. The main objectives of the project are (1) the investigation of novel computational mechanisms that enable computer systems to recognize intentional activities, (2) the development of an integrated software system to automate game interpretation and analysis, and (3) the demonstration of the impact of automated game analysis on application areas, such as sport science, football coaching, and sports entertainment. The results will be showcased in the form of an intelligent information system for the games at the Football World Championship 2006 in Germany.


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The physical setup that is currently developed by Cairos Technologies AG and the Fraunhofer IIS consists of tiny microwave senders are placed into the ball and the shin guards of football players. These senders broadcast signals with high frequency. Antenna-equipped position estimation systems determine the position of each sender with high accuracy. Because we cannot get real data of complete games until fall 2004 we currently develop our game analysis system for data from the RoboCup simulation league.

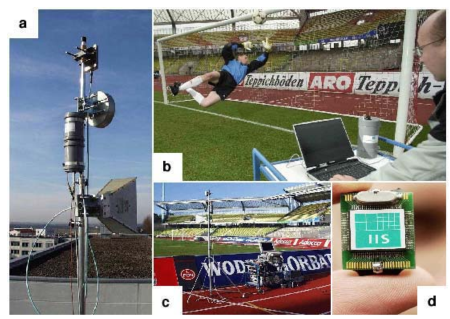


**Figure 1. Microwave-based position tracking system: (a) receiver; (b)&(c) installation; (d) sender.**

We have realized two example applications of sensor-based, automated game analysis. The first one is a personalized football home cinema, where a TV viewer can select the length of a game summary, personal preferences such as skillful dribblings, shots, good passing game and receives a TV game summary tailored to her/his preferences. The second application is an automated workbench for a football coach that supports the fast and informative game analysis.

## 2. Key Ideas of the Game Analysis

There are two important ideas that guide the design and implementation of our game analysis system: first, the acquisition, maintenance, and use of abstract game models and second, the idea of acquiring the model by inferring

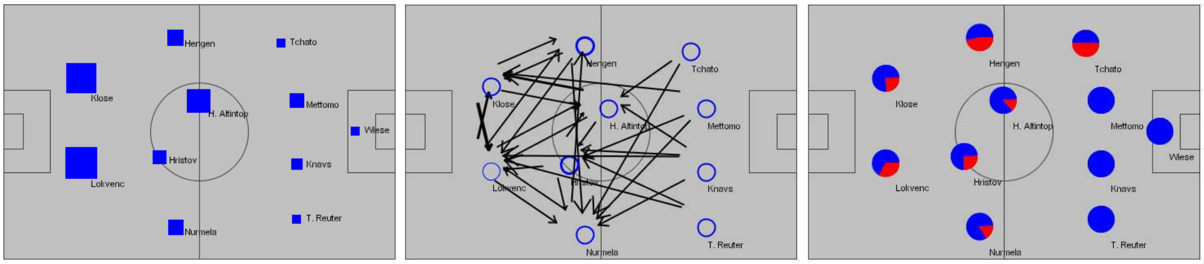


**Figure 2. Visualization of the number of passes played by the players. Number of successful passes (left), pass receivers (middle), and player specific success rates (right).**

the one that is most likely given the sensor data.

*Key Idea 1: Model-based Game Analysis* The first key idea is to perform football game analysis by first acquiring and maintaining a model of the happenings of the game and then use the model to solve the relevant reasoning tasks. A model is a simplified description or an abstraction of a system, used to reason about the system for explaining how sth works or calculating what might happen. Model building is the mapping of the real game process into an abstract representation formulated in features relevant for game analysis. The model is designed wrt. the goals of game analysis.

Our model for game analysis is a layered one. The most basic layer is the motion model. It represents the motions of players and the ball in a compact way that facilitates the recognition of game episodes. The second layer is the episode model. It segments continuous motions into episodes relevant for game analysis. Examples of such episodes are dribblings, passes, shots, offensive plays, etc. Episodes are characterized by a starting and ending time and a class that describes what is going on in the episode. The next higher level is the situative layer, in which the impact of players on the episodes is described. The representational means on this model layer comprise processes, interactions, and the role of players. The fourth layer is the tactical model that represents the objectives and classifies the tactical actions of the players. This model comprises player specific intentions and possible play actions like pass or shot opportunities. Finally, the highest layer is the analytical one that represents causal relations and analytical results.

*Key Idea 2: Probabilistic Estimation of Models* The second key idea is to pose the acquisition of game models as a probabilistic reasoning problem. Even in RoboCup simulation league where the game state is fully observable, is it not possible to perform the episode recognition correctly and accurately. Non-deterministic action execution and interference with other players often yields strong variations in the players' behavior. The real games are only partly observable. Because we only have position senders in the ball and in front of the players' shin, there are many situations in which we cannot decide which player has played the ball. In addition, since we perform real perception in the real world the sensor data received are sometimes unreliable and inaccurate. To deal with these issues we pose the model acquisition as a probabilistic inference problem. In this setting we want to determine the model $m^*$, which is the most likely one of all models $m$ given the sensor data $d$, that is $m^* = argmax_M P(M \mid D)$.

## 3. Querying the Game Model

One of the main criteria for assessing the motion and episode models is the degree to which they support the automatic analysis of football games. A typical abstract motion query is about the distance that every player was moving during a game episode, which can be ansswered using a simple pseudo mySQL query. Much of the information retrieved in such queries is already cached in the motion model, which makes answering these queries very fast. The passes played by the individual players can also be easily retrieved from the model. They are visualized in figure 2(left)). The query is even more informative if we group the passes by their players and receivers. The result can be visualized as a directed graph (figure 2(middle)) where the nodes are players and the thickness of arcs indicates the number of passes played between them. We can also query the fraction of successful and unsuccessful passes and shots and display them as piecharts.

## 4. Outlook

In our ongoing research we use the motion and episode models to acquire abstract models of more complex activities such as offensive plays, We also acquire and use motion and episode models to interpret and analyze games of the simulation league world championship. Our ultimate goal is to develop a comprehensive model-based game analysis system that works on real position data and is deployed at the soccer world championship 2006. For more information see: http://www9.informatik.tu-muenchen.de/fipm/.