A System for Radio Tracking of Team-Sports Players

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ABSTRACT

In this poster submission we present a high-level overview of a radio-based sensor system for tracking participants and equipment in ball games. We state the motivation for building such a system and describe the individual components in brief. We conclude by discussing the research challenges and the general applicability of the tracking system.

MOTIVATION AND OBJECTIVES

The state-of-the art sports tracking technology is largely based on severely limited video image processing. Inspired by advances in the field of real-time sensor data gathering, this proposal addresses the tracking issue by using radio-based sensors to deliver true *real-time* performance. The objectives of the system discussed are as follows:

- to provide a system for real-time radio-based accurate tracking of the *position* of the ball or other equipment and of the players in team ball games; to extend the system to measure physiological signals such as heart rate, blood pressure and body orientation;
- to communicate the tracked data securely and reliably in real-time to an interpreting component of the system;
- to process the tracked data in real-time and determine the occurrence and order of pre-defined significant events (i.e., a particular action by a particular player);
- to analyze and visualize the processed data, to instantaneously react to predefined events (e.g. signal an offside event to a referee) and to make the data available to further user applications;

The possible applications include, among others:

- improving refereeing decisions by delivering automated real-time game rules evaluation;
- improving coaching decisions by supplying detailed real-time statistics about the games' participants;
- improving the spectator experience by displaying detailed immediate game statistics and enabling the spectator to take the participants' perspective of the game;
- improving media broadcasts on sports events by supplying real-time statistics and enabling immediate detailed analysis of the game's events.

SKETCH OF THE MODULAR SYSTEM DESCRIPTION

The design of the proposed tracking system is divided into three groups of modules, the back-end, the processing units and the front-end (see Figure 1).

Back-end

The sports venue, players and the ball are instrumented with radio-based devices (mix of r.f. 'tags', transmitters and receivers), which are used to estimate distances (ranges) between devices. Various techniques can be used to measure ranges, including the Time of Arrival (TOA) and Differential Time of Arrival (DTOA) [1] of signals transmitted from the devices. The ultra wide band (UWB) radio sensor module provides distance estimates between the radio devices.

Processing Units

Instantaneous position and its high-order derivatives (e.g. velocity and acceleration) can be calculated from the set of distance estimates received from the UWB Radio Sensor module. Exactly how the (x,y,z) position at time t may be computed is under investigation. Techniques that use Bayesian [2] or Kalman [3] filtering or distributed location protocols based on orthogonal triangularization [4] have been proposed recently. Football players can travel up to 10 m/s, so finding the trade-off between position uncertainty, velocity and accuracy is a challenge.

Different ball games have different characteristics. Events occurring in football matches, for instance, may be unrelated to the ones observed in rugby. A domain knowledge-base module stores the semantics of a particular ball game. Such a database is useful for detecting game actions from the observed data. In a football match, for instance, the event of a free-kick may be followed by the action of 'goalkeeper jump'. A rule-based technique is introduced in [5], where football events are checked against event-rule specifications.

Front-end

Real-time visualization of the processed data enables immediate detailed analysis of the game. Other real-time tools assist the decision-making process of coaching and refereeing. Further modules present data such as match statistics and instant replays to the users of the system (spectators, broadcasters).

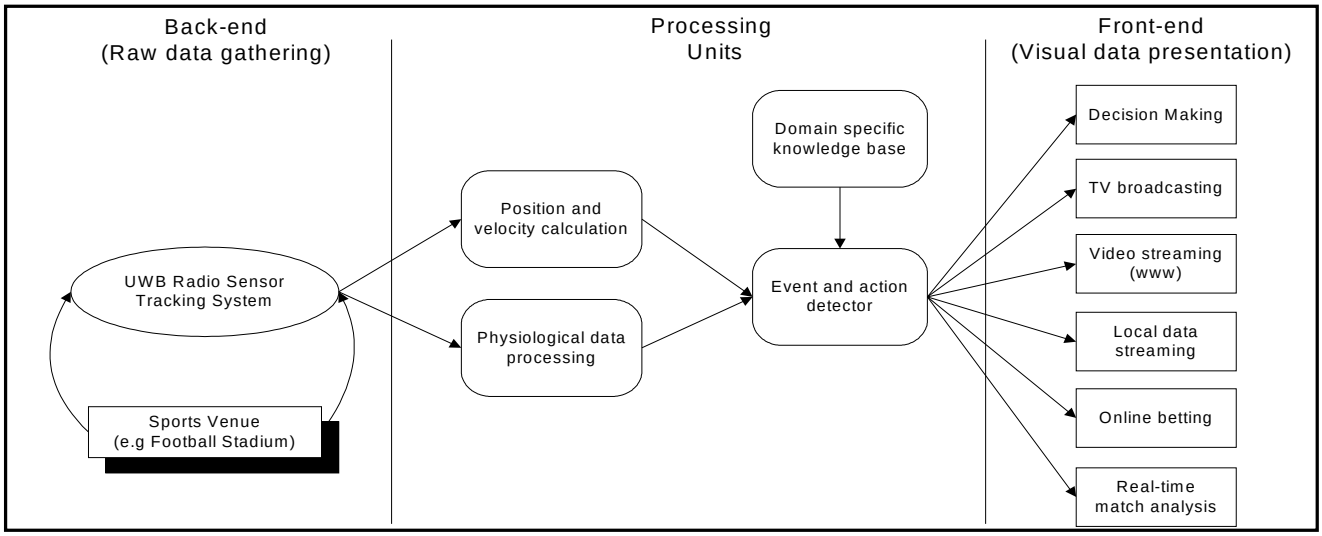

Figure 1: Sports Tracking System

Various media distribution techniques can exploit the system, including TV broadcasting, WWW and local data streaming. The latter may take advantage of the growing number of user mobile devices (e.g. IEEE 802.11 or Bluetooth smart phones), where data is streamed directly to the user devices using ad-hoc communications.

CHALLENGES

We list a few of the system design challenges below:

- *Multipath impairment:* signals from the radio-based devices propagate along the direct 'line-of-sight' path and a longer path where the signal reflects off the ground. The effects of this impairment must be taken into account in order to minimize the error in distance estimates;
- *Relative velocity of the tracked objects:* footballs can achieve velocities of 50 m/s and 1000 samples per second of the ball's position may thus be required to trace its precise trajectory. The design must reflect the right trade-off between velocity, accuracy and sampling rate;
- *Timestamp generation:* as electromagnetic waves propagate at the speed of light, radio-based tracking systems require a high time precision to distinguish between consecutive distance estimates. A timestamp in the order of nanoseconds may be needed;
- *Tracking an inflatable ball:* the 'tag' should not affect the playing characteristics of the ball, for example, it should not change its center of mass. An r.f. solution would require a simple printed antenna on the ball;
- *Detection of events and actions:* the domain knowledge base which contains the semantics for a particular ball game requires pre-analysis of games and equipment;
- *Real-time response:* fast data collection, processing and communication require adequate communication protocols between the tracking devices and the processing units;
- *Security:* deployment at high-profile events triggers concerns of data protection and device authentication.

CONCLUSION

The concept of real-time tracking of the sport events participants opens a new horizon for potential applications. Entire areas of human activity related to sports could be critically transformed, be it refereeing, coaching, media presentation, spectator experience or equipment data gathering. Furthermore, there is clear potential for applying such technology to other areas of human activity such as the areas of performing arts or healthcare.

Although the initial use of such a system would certainly be directed towards professional sporting activities, the projected costs of sensor-based platforms and the promise of full automation gives hope for such a platform becoming available to the general public in the foreseeable future.

REFERENCES

1. Vossiek, M., Wiebking, L., Gulden, P., Wieghardt, J., Hoffmann, C. and Heide, P. Wireless Local Positioning, IEEE Microwave Magazine 4(4), 77-86, 2003.
2. Smith, A., Balakrishnan, H, Goraczko, M., and Priyantha N. Tracking Moving Devices with the Cricket Location System. *Proc. ACM MobySYS'04*, Boston, MA, USA, 2004.
3. Fox, D., Hightower, J., Kauz, H., Liao, L, and Patterson, D.J. Bayesian Techniques for Location Estimation. In *Proc. Workshop on Location-aware Computing*, Seattle, WA, USA, 2003.
4. Pias, M., Crowcroft, J., Wilbur, S., Harris, T., Bhatti, S. Lighthouses for Scalable Distributed Location. In *Proc. IPTPS'03*, Berkeley, CA, USA, 2003.
5. Tovinkere, V. and Qian, R.J. Detecting Semantic Events in Soccer Games: Towards a Complete Solution. *Proc. ICME 2001*, Tokyo, Japan.