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Analysis of Indoor Team Sports Using Video Tracking and Wireless Sensor Network

1. Introduction

Our analysis system, consisting of a high resolution video system together with a wireless sensor network, is used for collecting position and physiological data of sport players during training or competition. The combination of the two data streams provides a new type of performance analysis and visualisation solution for indoor team sports.

2. Methods

A wireless sensor network is used to collect physiological (heart rate with optionally skin temperature/conductance) and kinematical data (speed/distance) of each athlete in real time. The system constraints include: the data collecting occurs in an indoor environment with the size of at least 40m x 20m, the number of athletes whose data can be collected in parallel is up to 30, the sensor node is sufficiently compact to be worn by the athlete and the battery life time of each sensor node is at least 24 hours of use. Finally, a proper quality of service, e.g. less than 10% packet loss for each sensor node, should be met so that the continuity of data for each athlete is guaranteed.

We have applied the shirt-integrated electrodes for our heart rate sensor node (HRSN). As for the speed/distance sensor node (SDSN), we considered to use an acceleration sensor. For both sensors, the generated signals must be first digitalised and then processed by respective algorithms to output the intended features (physiological and kinematical data). Our sensor node is composed of a sensor signal processing module and a radio transmission module. The former includes the analog pre-processing circuits, a MCU (Micro Controller Unit) with the A/D converting function and the software for the signal processing algorithm running on the MCU. This module can optionally output two kinds of data to be transmitted, the calculated feature or the original but digitalised sensor signal. The latter module is composed of a radio frequency (RF) transceiver and a dedicated MCU for running the software.

The key task of the wireless sensor network is to transmit the measured data to a central station. Bluetooth is the first candidate to consider as it is widely applied as a cable replacement solution. However, its small network capacity, up to 3sec activation time and high power consumption prevent it to be the appropriate technology for our application. Compared to Bluetooth, ZigBee sacrifices some performance on data rate and reliability to save hardware complexity and power consumption. Furthermore, it also brings the advantages of short activation time (15ms) and large networking capacity. Unfortunately, our implemented prototype shows that even with the simplest operation mode, a general coin cell (CR2032) is not suitable for the peak power requirements of the HRSN (90mW). Applying two coin cells makes the resulting HRSN beyond the prescribed size constraint.

Based on the above trials on Bluetooth and ZigBee, we have sensed that the peak power consumption is the most critical problem that we must deal with. A new technology called ANT comes into our sight. ANT is advocated by Dynastream Innovation Inc. which is actually a specification covering the physical (PHY) layer, media access control (MAC) layer and the networking layer. As our application only requires a multipoint-to-point (also called star) topology, we decided to use our own software instead of ANT-specified MAC & routing software to further reduce the peak/average power consumption. Together with the selected MCU that controls the RF-Chip (nRF24L01, an ANT-compatible RF transceiver from Nordic Semiconductor), the peak power consumed for transmission is about 35mW (11.67mA @ 3V) and the power consumed during the sleep mode is about 21µW.

The above communication module is only applied by the HRSN. For the SDSN, we adopt the commercially available product from Suunto Oy due to the unavailability of the Dynastream acceleration sensor.

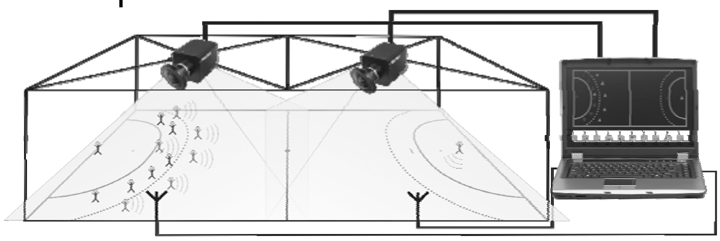

Figure 1: Developed system structure

In physical and tactical analysis of indoor sport games path information of the players is of great importance, also video based visualisations can be much more informative than just presenting the results in tabular or graphical form. So, in order to acquire players' path information, a training session or game is captured by a video system consisting of two cameras which are placed at the hall ceiling. The video data are post-processed in order to identify positions of the players and to track all players on the field by means of an enhanced template matching algorithm which is a technique in digital image processing for finding small parts of an image that match a reference image.

Template matching works as follows: the template (reference) image is compared to all parts of the searched image and a measure of similarity is computed in each comparison step. The parts which give high similarities are more likely to contain the searched pattern.

Due to the highly dynamic and changing nature of sport players' movements, the use of a static template is not optimal. Also, the use of a large number of templates is not possible because there are many potential orientations for each player with respect to the viewing angle; so one dynamic template is used. At the beginning, the user selects a sub-image to be taken as the initial template. When the position with a maximum similarity in the next frame is found it is taken as the template for the following frame and so on. One pre-assumption of this update procedure is a small change in the shape of the tracked object between two successive frames. The higher the frame rate the smaller the change between two successive frames. In our implementation the frame rate is 30fps (frames per second) which gives good results.

In multi-target tracking, taking into account the assumption that two players cannot occupy the same place at the same time, spatial information from other trackers can be used to enhance the tracking, e.g. to mask out areas where we are sure that the tracked player will not occur in. Also a background model is computed and subtracted from each frame to get only the ROIs (Regions of Interest) in the image. If errors occur in the tracking a graphical user interface is also available in order to interact manually with the tracking algorithm for error correction.

The video data flow consists of several steps: first the frames are acquired from the video cameras and saved as digital raw video files, then they are used as input for the tracking algorithm explained above. Finally, the video data is used together with the tracking and sensor data to produce a video with annotations. From the tracking data the path of each player as well as the corresponding calculated information such as distance, speed and acceleration can be computed.

3. Results

Our developed HRSN can transmit every individual heart rate so that a beat-to-beat analysis becomes feasible. Moreover, both data (HR & speed/distance) can be illustrated and analysed online by the same software. For a general use[1] the battery life time can be more than one year (for a 220mAh CR2032) even if the communication module keeps on operating.

Regarding the video system, the processing time for tracking 5 players in a basketball game without correction is 10fps. The average number of corrections is 0.005 corrections/frame/player. The average time for manual correction is 10sec per error. Finally, the average processing speed including correction is 2.86 fps.

By combining the two streams of video and physiological data, we can correlate the instantaneous body conditions with the corresponding game situation

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1 Provided that each packet requires 300µs to be transmitted (32Bytes@1Mbit/s) and the packet rate is 5Hz. The required peak current is far below the one that a standard coin cell can provide (11.67mA vs. 20mA).

based on the performance analysis of each player. With these data, an individualised training plan for every player can be generated. Furthermore, the resulting tactical analysis on the previous games is very helpful to improve strategies for the future trainings and games.

One application of our system is the substantial evaluation of the covered distance in male handball games after applying a new rule in 2001 (IHF, 2005). First results show that the covered distance has increased significantly (Boettcher, 1998, pp 92 - 99; Baumeister, 2008).

4. Discussion

For the first time it is possible to visualise the actual performance profiles for the players of indoor ball games in training or competition and to apply this knowledge to obtain the optimum training pattern and game strategy.

As an enhancement for the sensor network we apply receiver diversity technology for better energy-efficiency and communication reliability, respectively. Our system also provides large flexibility for further designs/improvements, e.g. different heart beat algorithms (QRS Detection) can be implemented on the MCU, the potential to increase the network capacity and the possibility to reduce the packet loss.

In the video tracking system template update causes the problem of small template drifting outside the tracked part. To overcome this problem and to reduce the number of manual corrections we are enhancing the tracking by making use of colour information.

Authors

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IHF – International Handball Federation (2005), IX. Rules of the game a) Indoor handball (Page 32, § 10:4)