Use of On-Body Sensors to Support Elite Sprint Coaching

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Abstract

The purpose of this project was to evaluate a custom built foot pressure sensor system (*StrideSense*) for elite sprinting. *StrideSense* is extremely lightweight, wireless sensor system capable of kHz sampling and automated data processing, meeting the specific requirements for use in running spikes, coaching support and scientific analysis. Sprint coach interviews revealed the need for the development of such a pressure sensing system to non-intrusively monitor athletic performance throughout a sprint run. Foot contact data contains essential information on a number of parameters including velocity, step frequency and limb asymmetries. The aim of the project was to obtain user-specific system and data feedback from sprint coaches and athletes to evaluate the ease of use and usefulness of *StrideSense* as well as the perceived relevance of the data provided to coaching and performance monitoring.

KEY WORDS: WIRELESS, ATHLETICS, FSR, INSOLES

Introduction

Lightweight, wireless sensor systems offer novel possibilities for the investigation of athletic performance. Traditional motion analysis methods quickly reach their limits of practicality when applied to a dynamic sporting setting. They can be disruptive to the sporting activity and data processing and interpretation can be cumbersome and difficult for the coach. Efforts have been made to resolve this problem through the use of on-body sensors. Examples include the work by Michahelles and Schiele (2005) for skiing, Aylward and Paradiso (2006 and 2007) for dancers and Purcell et al. (2006) for running. However, due to the high sampling rates required, the application of this technology to the analysis of sporting technique has not yet been exploited to its full potential.

Track and field athletics and the sprinting events in particular present a challenging environment for the investigation of technique using on-body sensors. Sprinting is a highly technical discipline involving a clearly defined goal, repeated strength, conditioning and technical training exercises and close athlete / coach interaction to optimize movement routines. While coaches currently use a variety of basic tools to track performance (e.g. light-gates, stop watches and video cameras), it is thought that the use of wearable, non-intrusive sensors, augmented by video-footage, may have the potential to provide domain-specific data that will assist the coach and athlete in preparation for competition.

In order to investigate the potential benefits of the use of wireless technology to assist coaches in the sprint disciplines, a series of semi-structured interviews with a set of leading coaches were performed (Thomson et al. 2009). These interviews revealed a number of parameters that are of particular interest to the sprints coach, including the action of the arms, contact of the foot with the ground, hip height and the athletes running posture. Particularly the contact of the foot with the ground was thought to be of interest as coaches believed that there may be a strong relationship to running velocity and is information that is currently not available. The interviews furthermore revealed the need for accurate and meaningful performance data to create a reliable reference point to track athlete development over time and to enhance coach / athlete communication. It is therefore not only a real-time but also a long-term activity requiring a definitive sensor data record.

As part of the SESAME project (SEnsing for Sport and Managed Exercise) a wireless and extremely lightweight foot pressure sensing system was developed (*StrideSense*). This paper will summarize the developmental steps of the *StrideSense* systems that were taken to extract and visualize domain-specific performance data for sprinting. This will be followed by an outline of the current system implementation and validation to ensure capture of accurate, automated and meaningful data for the coach and researcher. Finally, the plans for future work and further system developments will be covered.

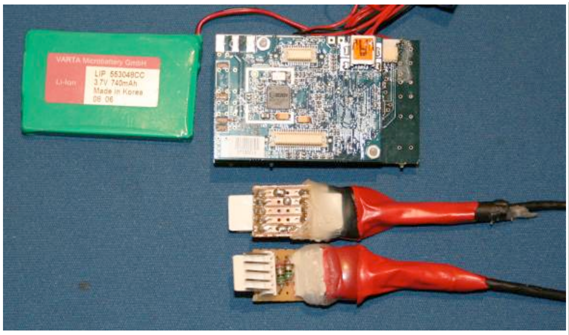
Technology Demands

Further to addressing the specific knowledge of elite coaches on ideal sprinting technique and the methods for acquiring this knowledge, the coaching interviews provided essential guidance on the technological prerequisites of the use of wireless sensors in athletic monitoring. While current biomechanical measurement technologies (e.g. force-plates and motion capture) are highly accurate they are also generally too large and heavy for on-body use and require considerable resources for purchase, maintenance and use. Measurement within the dynamic sporting setting therefore requires on-body sensors to be extremely small and lightweight to ensure minimal interference with the athlete and the sporting task. Moreover, effective use of sensor data for active coaching support requires that data are derived and visualized with minimal delay between the end of the run and the athlete returning for coach feedback. This means that ideally the measurement system records and transmits data wirelessly, automatically processes raw data (using specific algorithms) to extrapolate meaningful performance data and visualize these data in a comprehensible fashion to meet the sprint coach user demands.

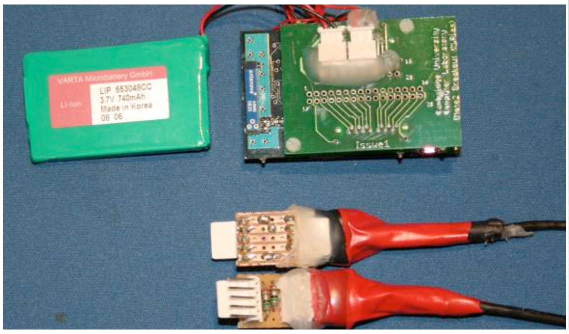
System design and validation

The *StrideSense* system was developed with the aim of addressing the domain-specific requirements described above. Foot pressure data is registered using force sensing resistor (FSR) sensors mounted to a standard insole (see Figure 1c). FSR technology, compared to alternatives such as piezo-electric sensors, was found to be the ideal option for obtaining high frequency data from a highly robust and flexible sensor, essential for use in hard-soled, formed, sprinting spikes. FSR sensors are attached to a central sensor node responsible for data logging and wireless communication with a trackside laptop. The node consisted of a Crossbow Imote2 sensor board (Crossbow 2009) and Marvell 8686 WiFi chip (Marvell 2009) (total weight 32 g, see Figure 1 a) and b)), worn at pelvis height by the athlete. Data is off-loaded from the athlete via a WiFi network both during and immediately after each repetition.

a)



b)



c)

Figure 1 a) and b) show the sensor node consisting of the Imote2 sensor board and the Marvell 8686 WiFi chip. Power is supplied using a Li-Ion battery and connectors for the left and right insole are shown at below the node. Figure c) shows the underside of the insoles used, with FSR sensors attached to the anterior aspects of the insoles, on the lateral side of the ball of the foot (*midfoot*) and the area of the great toe (toe).

Data analysis and visualization is performed on the trackside laptop using custom software (see Figure 2). The visualizer has the ability to display video clips synchronized with the sensor data.

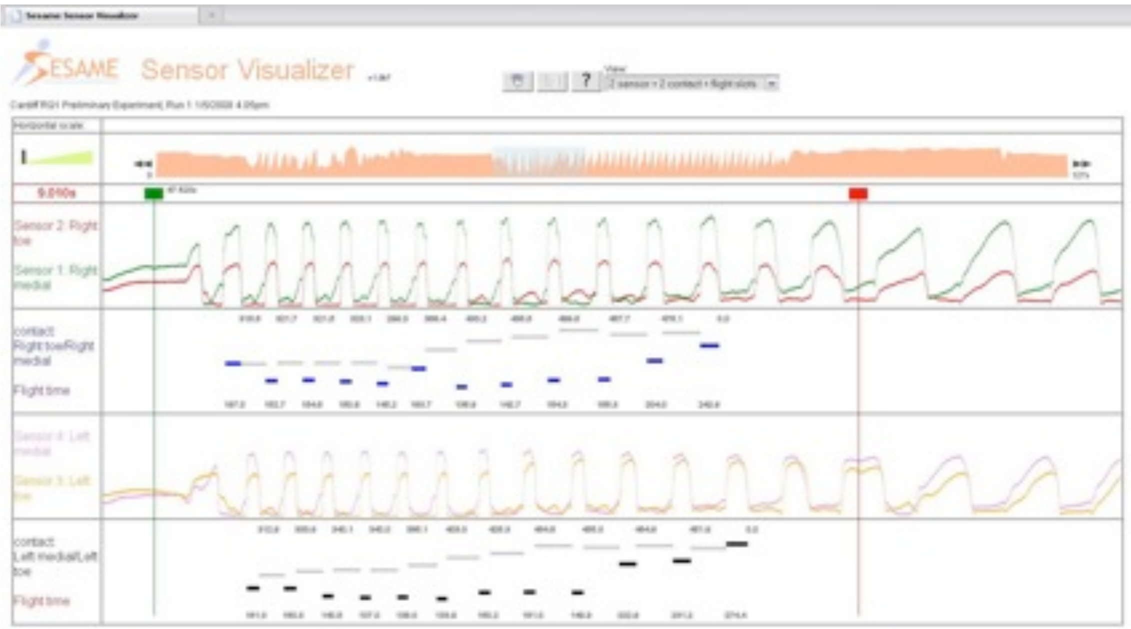


Figure 2 Custom web-based visualizer software for the display of raw and derived sensor data as well as video footage collected during a repetition. Visual options for data magnification and scrolling are provided. Raw sensor data plots are displayed with derived contact and flight times displayed below. Furthermore, data export functions are available, controlled by start and end cursors visible at the start and end points of the data streams (vertical lines).

In order to provide instant data on contact times in sprinting, a fully automated custom-made detection algorithm was developed. Data from the toe and midfoot sensors (see Figure 1c) was used for accurate contact identification. As sprinting uses a front and midfoot contact only, it was not necessary to include a heel sensor for this application. The accuracy of the system and algorithm for the identification of contact times was validated using *StrideSense* (2 kHz) and a force plate (1 kHz). Data for the start, the acceleration and maximum velocity phases were analyzed to verify accuracy during these distinct phases. Currently available data (38 contact events) indicate an RMS error of <1ms which provides a very favorable accuracy metric.

Current application and future application

In order to enhance our understanding of the performance characteristics of sprinting, the *StrideSense* system has been used for the investigation of the relationship of contact time and velocity in 60m maximal sprinting (Kuntze et al. 2009) (see Figure 3). While these investigations are currently on-going, initial data indicate a usable, individual athlete based relationship between contact time and velocity that may provide useful coaching information for the tracking of sprint performance.

Figure 3 Current application of *StrideSense* for the investigation of contact time and velocity in sprinting, with CODA scanners being used to provide foot contact time validation data (Bezodis et al. 2007).

To allow for a truly wireless application, current work is focused on removing the wired connection between the FSR sensor and the Imote. To achieve this aim a sensor cluster system is proposed with a central Imote and peripheral Ions located at the ankle of the athlete and connected to the FSR sensors. This will provide a truly wireless sensor system, opening up new application settings and research opportunities. New research areas of immediate interest are both the short (100m and 110m) and long (400m) hurdle events. Preliminary coach interviews revealed that hurdles coaches may assess hurdling performance and competence based on a variety of split time measures as well as visual assessment of hurdling form. Since hurdle locations on the track are specified it appears eminently possible to extend the recording capabilities of the *StrideSense* system to the automated recording of split times between hurdles, step frequencies and flight times over hurdles. Foot pressure data from a hurdling pilot study identified a number of key parameters that show the potential for automated hurdle event identification. These initial data will be further assessed to verify the automation opportunities and the potential for a reliable, hurdling-specific analysis system.

Conclusions

The current *StrideSense* system achieved the aim of providing a reliable, lightweight and non-intrusive method for sprint performance investigation. Domain specific information is relayed to the coach in an understandable manner and work is being undertaken to extract further sprint performance data. There are further opportunities for system enhancement which are the focus of current development efforts. These developments will aid in providing a robust and usable system for regular use in sprint training as well as expanding the investigation of performance for further sporting disciplines.

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