TOWARDS AN AUTOMATED FEEDBACK COACHING SUPPORT SYSTEM FOR SPRINT PERFORMANCE MONITORING

Gregor Kuntze[1], Lawrence Cheng[2], Huiling Tan[3], David G. Kerwin[1], Stephen Hailes[2] and Alan Wilson[3]

Cardiff School of Sport, University of Wales Institute Cardiff, Cardiff, U.K.[1]
Department of Computer Science, University College of London, London, U.K.[2]
Structure and Motion Lab, Royal Veterinary College, Herts, U.K.[3]

The purpose of this study was to investigate the feasibility of developing a cost-effective, automated performance feedback system to support sprint coaching. The proposed system is designed to deliver step length, step frequency, contact time and 10 m split time information of multiple athletes training on an indoor track. An integrated systems approach was chosen combining the novel Pisa Light-Gate (PLG) and Step Information Monitoring Systems (SIMS). Current results indicate data accuracy of RMS 1.662 cm for step length, RMS 0.977 ms for foot contact time and a split time detection accuracy of 8.45 ± 6.85 ms. These results suggest that the proposed integrated system, using off-the-shelf equipment, would go beyond currently available coaching tools by providing automated and highly accurate sprint performance information for multiple athletes.

KEYWORDS: foot contact time, split time, step length, step frequency, athlete support.

INTRODUCTION: Performance monitoring systems for athletics have, to this point in time, provided either very basic information, involved considerable time to set up or required extensive post-processing efforts and a high cost of purchase. Thomson et al. (2009) showed that elite sprints coaches are keenly interested in a number of performance and technique related parameters in order to quantitatively monitor the development of their athletes over time. However, the restrictions of currently available systems in terms of their ease of use and databasing capabilities have largely prevented their routine use in training. Furthermore, thus far the information that can be obtained by the coach is largely restricted to timing data over specified distances and no quantitative feedback information relating to aspects of technique have been made accessible to the coach.

One aspect of sprinting technique that has been highlighted as being of interest to the coach is the interaction of the foot with the ground (Thomson et al., 2009). The interaction of the foot with the ground is represented by a number of variables including step length (SL), step frequency (SF) and contact time (CT). These parameters and their interaction for the sprint start and maximum velocity phases have received substantial interest in the literature (Ae et al., 1991; Bezodis et al., 2008; Coh et al., 2006; Cronin and Hansen, 2006; Frishberg, 1983; Hunter et al., 2004; Kristensen, 2006; Kuntze et al., 2009; Luhtanen and Komi, 1978; Mann and Herman, 1985; Salo and Bezodis, 2004). However, due to a lack of long-term, inclusive set of sprint performance data, there is as yet no clear consensus as to the benefit and feasibility of altering any one of these parameters in order to enhance athlete sprinting velocity.

In order to address the need for enhanced accurate information availability for sprint coaching using cost-effective equipment, it was decided to utilise an integrated systems approach combining a permanently installed multi-lane split-time monitoring system, the Pisa Light Gate (PLG) system (Cheng et al., 2010), with a novel foot parameter detection system, the Step Information Monitoring System (SIMS). PLG supports long term databasing and on-line review of 10 m split time measurements for a 60 m indoor running straight for multiple athletes running at a time. The system is operated using a WiFi controller (iPod Touch, Apple Inc.) which also allows for the immediate display of timing information. The SIMS system uses integrated track-side low-cost cameras and on-body foot pressure sensors for detecting foot CT, SL and SF. The use of an integrated approach for the development of SIMS allows for the utilisation of the existing PLG hardware and software infrastructure providing an ideal basis for the expansion of sprint related measurement capabilities and the instantaneous display of feedback information. However, the suitability of cost-effective equipment for high performance sprint monitoring – which requires high level of accuracy - is not known. The aim of this study was to use a prototype of the proposed SIMS system to assess the feasibility and accuracy of an integrated system capable of providing instantaneous performance and technique related feedback to the athletics coach.

METHOD: One recreational athlete (29 yrs, 81.0 kg, 1.84 m) gave written informed consent to participate. He was asked to perform six sprint start and maximum velocity runs on the 60 m indoor running track of the National Indoor Athletic Centre (NIAC) in Cardiff, UK. The participant performed his normal warm up routine before performing the sprint runs. Upon completion of the warm up the participant was fitted with two custom built pressure sensing insoles utilising force sensing resistors (FSR). These acted as controllers for two pairs of super-bright light emitting diodes (LEDs) which were mounted to the sprinting spikes worn by the athlete (one on the lateral side of right foot and one on the medial side of the left foot) triggering the activity of the LEDs during the support phase of the sprint cycle (see Figure 1a).
SL data were collected using SIMS, installed at the final quarter section (45 to 60 m) of PLG. SIMS consisted of a 15 Hz Point Grey video camera (CMLN-13S2C-CS) operated by a laptop computer. The camera was located in the roof section of the athletics centre giving a total field of view (FoV) of ~15 m. For FoV calibration, lane 4 of the running straight was marked at 0.5 m intervals using the lane edges and the centre of the lane (see Figure 1b). The lane was therefore divided into multiple virtual zones, enabling accurate camera calibration for SL calculation using a custom-designed, geometry-based calibration algorithm. SL was determined based on the LED light impulse during support: each red dot in the video images therefore represents the position on the ground where the foot has landed. SL was calculated based on the horizontal distance between two subsequent red dots in relation to the underlying calibration reference points (see Figure 1b), which are needed once when setting up the (fixed-location) camera.
SL validation data were collected using an automated 3D motion analysis system (CODA), recording the horizontal displacement of active markers (at 200 Hz) placed superiorly to the LEDs used for the SIMS system. Four CODA scanners were placed unilaterally along the side of the sprint straight providing a total FoV of ~16 m (see Figure 1b).

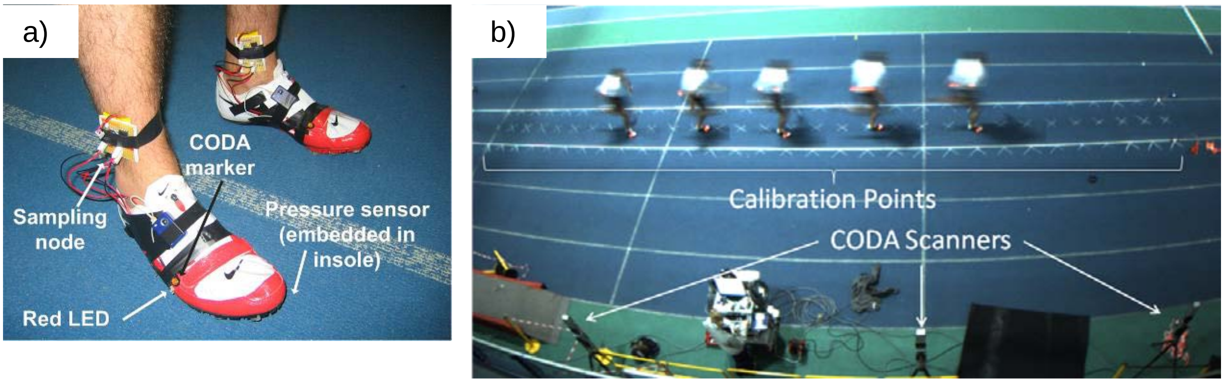

Figure 1. a) The SIMS insole-based pressure sensing prototype (with LEDs); b) a birds eye view of the total SIMS FoV showing the participant, calibration points and CODA scanner positions.

RESULTS: SL values computed from SIMS were compared to those from CODA (see Table 1). The absolute RMS error was larger for the entire 15 m FoV than the central 10 m section of the FoV due to the effects of lens distortion. Figure 2 displays all SL data for the central 10 m section of the FoV using SIMS and CODA.

Table 1. Difference in SL determined using SIMS and CODA

	15m FoV (cm)	10m FoV (cm)
RMS	2.417	1.662
Max	9.150	4.528
Min	0.001	0.001

DISCUSSION: The findings of this investigation indicate very encouraging initial levels of accuracy for the automated determination of SL using the SIMS system. Step length data were in agreement with the validation measurement technology (CODA) showing a comparative absolute RMS error of < 2 cm for a 10 m FoV (see Table 1). Importantly, no foot/ground contact events were missed by the SIMS system indicating that a 15 Hz sampling rate is sufficient for the determination of SL in sprinting with contact times unlikely to be less than 90-100 ms in duration (Kuntze et al., 2009). The level of accuracy at this early stage of system development may be improved by the use of additional reference points in the calibration field. It provides clear indication of the effectiveness of the automated detection algorithm for providing gold-standard comparable step information.
Furthermore, this level of automated SL determination accuracy is encouraging for the purpose of inclusion of SIMS within the proposed integrated system framework. Previous validation and application testing has demonstrated high levels of accuracy for the automated determination of 10 m split times using PLG (8.45 ± 6.85 ms) (Cheng et al., 2010) and automated foot contact time determination using FSR based insole technologies (absolute RMS 0.977 ms; max error 1.98 ms; min error 0.001) (Kerwin, 2009; Kuntze et al., 2009; Taherian et al., 2010). Importantly these levels of accuracy are achieved using affordable, and readily available technologies (SIMS camera ~£200; PLG retro-reflective light gates ~£60 each; and FSR insole hardware ~£5 per pair) which is essential for providing cost effective performance monitoring solutions to coaches and athletes.
Future developments of the system are focused on the full implementation of SIMS as a completely integrated part of the PLG – SIMS Integrated System (IS) and the expansion of SIMS to cover the entire 60 m length to match the measurement capabilities of PLG. The integration of SIMS derived SL information with PLG and FSR insoles will be a significant advancement of measurement capabilities in athletics. It creates the possibility of simultaneously collecting long-term data on a variety of sprint performance parameters including 10 m split times, step length, contact time, flight time and step frequency as well as step by step changes in athlete velocity. It is anticipated that the creation and regular use of this integrated system will advance our understanding of the contributors to athletic performance by providing long-term, multi-variable, athlete-specific performance data. This may aid in the assessment of the benefits and feasibility of alterations to any one of these parameters in order to enhance athlete sprinting velocity.

CONCLUSION: This study demonstrates the feasibility of developing a novel, accurate, measurement system using cost-effective equipment for the assessment of performance and technique in sprinting and related athletic disciplines. The integrated PLG and SIMS systems provide a unique opportunity to gather long-term athlete record data which is anticipated to be highly useful for the coach in order to track performance changes and gauge the effectiveness of training methods.

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