WILD MONITORING: LINKING PERFORMANCE, PHYSIOLOGY AND BIOMECHANICS LIVE

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Mobile communications are enabling monitoring in the wild: the natural performance environment. This paper presents an overview of the use of the CSIRO Knowledge Experience Network (KEN). KEN Combines wearable sensors with mobile devices and other performance measures to link biomechanics with physiological parameters and performance measures. The system can be used in diverse training and competition environments, as illustrated via examples in laboratory testing, elite training and international competition.

KEY WORDS: field monitoring, electronic textiles, smart phones, cycling, kayaking.

INTRODUCTION: Interaction between athletes, coaches and sports scientists is challenged by distance, data and environmental conditions, but is crucial to the development of the highest levels of performance and achievement. Field locations can also make it difficult for specialist staff to routinely attend training sessions and access and comment on immediate and historical data. The function and form of smart phones are enabling new measurement and interactions in the performance environment of many sports. Smart phones can enable combined measurement of task performance, physiological condition and biomechanical motion in diverse training and competition environments when combined with wearable systems, including electronic textiles, such as strain sensors, bio-potential electrodes, and pressure sensors (Helmer, Mestrovic, Taylor, Philpot, Wilde & Farrow 2010). Information systems for sports training that are smart phone based are appealing due to device familiarity, form and configurability. Convenience is maximized by transferring training data to a server automatically, ideally 'live' so that it can be available to coaches during training, and by providing a platform for communication. This paper presents an overview of the use of the CSIRO Knowledge Experience Network (KEN).

METHODS: The KEN system facilitates capture, storage and access to performance data and audio visual communication between various distributed elements and portals using mobile devices as a common field platform. KEN is being developed and applied in sport to improve athlete, coach and scientist interaction, accelerating performance analysis and feedback. The KEN components are depicted schematically in Figure 1 and the system often combines biomechanics with physiological and other performance measures.

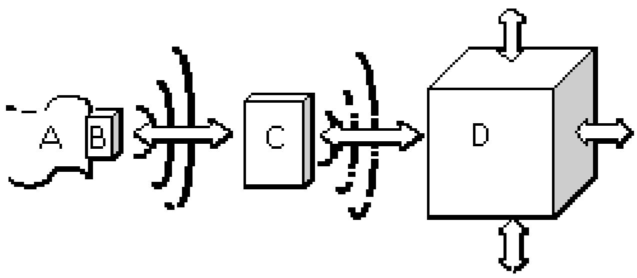
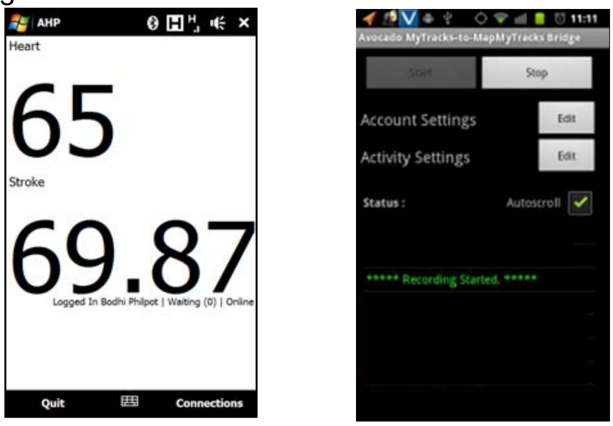


Figure 1: System architecture, A: wearable sensor, B: wearable electronics unit, C: local computing device, D: remote server.

The sensors (A) include combinations of electronic textiles (such as limb flexion garments, respiration bands and heart rate bands as discussed in Helmer et al. 2010), coupled with a custom configurable wireless electronic transmitter (B) to live-stream measurements via Bluetooth to a nearby mobile device (C) (see also Helmer, Blanchonette, Farrow, Baker and Phillips 2012). The mobile device may also integrate data from onboard accelerometers, GPS units and other external devices such as conventional power and cadence units (e.g. the SRM unit used by cyclists) using the device's Bluetooth and ANT+ radio. Typically the mobile device has customised logging and feedback software to capture and synchronise data and possibly display real-time metrics on the onboard screen. The mobile application also directs the data across a network to online information storage and handling systems (D) to allow real-time display of current performance data via web portals. The first system embodiment (KENv1) had multiple wearable sensors connected via Bluetooth to a HTC touchpro smartphone with a windows mobile operating system. KENv1 utilised a single data store and the use of multiple sensor systems meant data sources were combined as a single synchronised multidimensional time-series of data. A second embodiment (KENv2) used a consumer smartphone (Sony Xperia x10 minipro) with a custom application that made use of existing third party smartphone applications (Google MyTracks) for the Android operating system (v1.8), and to stream live power, heart rate and position data to an existing web portal (MapMyTracks). KENv2 was trialled in international competition at the Tour Down Under cycle event in Adelaide in January 2012. Smartphone interfaces used in KENv1 and KENv2 are shown in Figure 2.

(a)



(b)

Figure 2: CSIRO KEN system smart phone interfaces (a) KENv1 with summary metrics, (b) KENv2 simplified Start/Stop.

Use of the KEN system in three performance settings is shown in Figure 3.

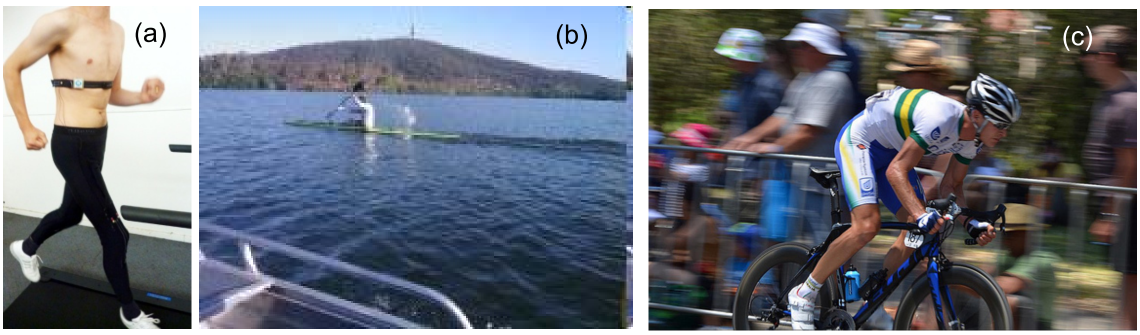


Figure 3: CSIRO KEN system use in performance settings (a) Laboratory (b) Elite kayak training and (c). Elite cycling competition.

RESULTS AND DISCUSSION: In the laboratory – understanding what's important: Within the performance community there is a wide range of uses for training data and different levels of detail are required. For example, in kayaking an athlete and coach may desire knowledge of stroke rate and distance during training, whereas biomechanists may desire samples of highly detailed data to analyse technique, and all need summary data to monitor training levels and longitudinal trends. Constructing a field system requires the integration of insights from experts including coaches, athletes, biomechanists, physiologists, and system engineers to form an agreed set of metrics of interest that can be implemented into information flow management and data interfaces. A collective appreciation of sensor function and typical signals including acceptable rates for sampling and methods for characterising and summarising data is essential. Figure 4a shows an example of high sample rate primary data from wearable sensors linking physiological and biomechanical activity which have been used to derive average measures (respiration rate, heart rate and limb cadence) for longitudinal analysis shown in Figure 4b.

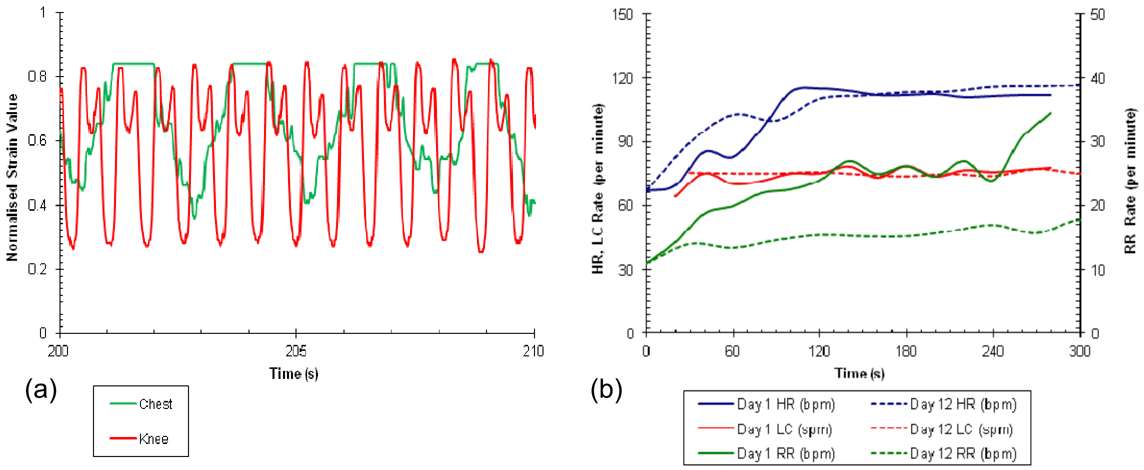


Figure 4: Linking biomechanics and physiology in the laboratory (a) High sample rate normalised strain of chest and knee textile strain sensors (b) Algorithmically derived comparison of two performances of same subject on two different days after respiration training: leg cadence (LC, steps per minute (spm)), heart rate (HR (bpm)) and respiration rate (RR, (bpm)).

Mobile phones impose constraints such as limited processing power, specific wireless frequencies, limited battery life, a requirement to still operate as a phone, and unstable and costly communications bandwidth which all need to be considered as part of information management design. Detailed knowledge of existing field measurement systems is also required to integrate and synchronise measurements in useful ways (e.g. such as integrating bike computer measures of power and cadence etc). To most efficiently utilise live monitoring platforms, knowledge must be algorithmically embedded into the information stream so as to simplify and optimise system operation. Activity classification is required to record and summarise data appropriately, i.e. so that training can be separated from non training and to detect when particular training activities are occurring as discussed elsewhere (Taylor, Abdulla, Helmer, Lee & Blanchonette 2011).

In the Wild: communicating what's important: Figure 5a shows an example of live high sample rate monitoring (>100 Hz) of elite kayak training technique using a smart textile in the field where the performance measurement is relayed in real-time to a coach on a chase boat and a sports scientist in an office circa 2009. Figure 5b shows a live competition interface of low sample rate monitoring (1–10 Hz) circa January 2012 (see http://www.mapmytracks.com/events/tour-down-under-2012). The timeliness of the web portal is constrained by the rate at which the information is received and updated. In training environments it is possible to stream high sample rate data, whilst in competition environments it can be very difficult to maintain information flow due to significant network demands. During the Tour Down Under the KENv2 total system latency was approximately 10 seconds and the cost per rider was 1c/100kb (or 27c per hour).

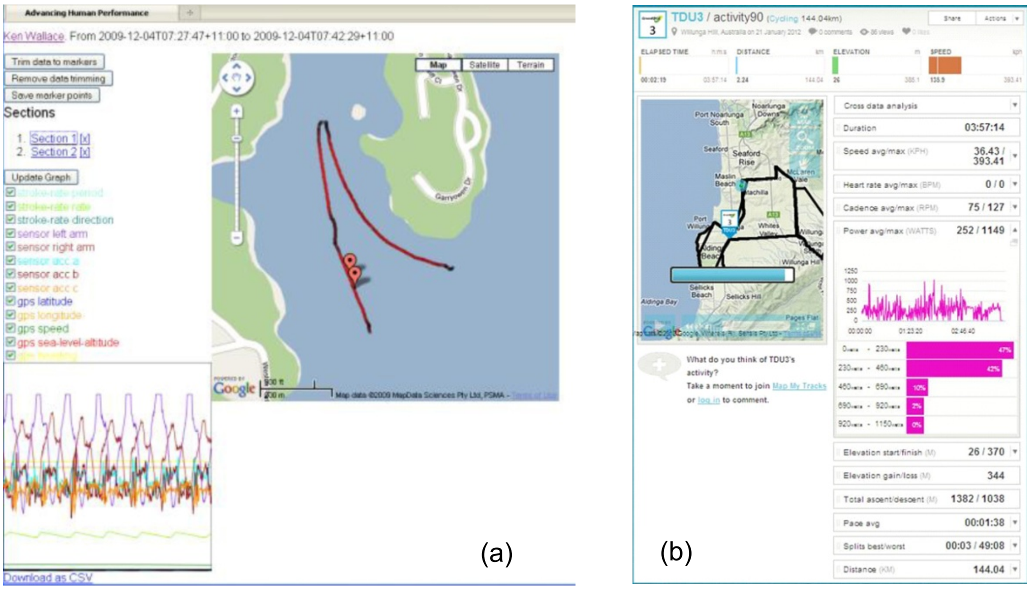


Figure 5: (a). Live training interface for High Sample Rate monitoring (>100 Hz) circa December 2009, and (b). Low Sample Rate Monitoring (1–10 Hz) Live competition interface for individual rider circa January 2012.

Portal interfaces, such as that shown in Figure 5, provide data visualization, control and interaction that allows users to filter data, to see detail of effects of adjustments to technique immediately and so make more immediate informed instruction. The system allows comparisons of individual performances and group measures. Improving the usability of these portals can mediate some of the frustration that can be present in challenging field environments and requires continual dialogue within the development team.
Finally, using wild monitoring systems in international competition requires the technology use to not distract competitors and support staff, comply with competition regulations, and be highly robust.

CONCLUSION: Mobile devices and wearable sensor systems with real-time data streaming to cloud systems are enabling widespread field measurement of information related to performance, physiology and biomechanics. This capability is evolving rapidly and requires the integration of biomechanical insight into information flow management and data interfaces.

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Acknowledgement: The authors wish to thank GreenEDGE cycling, Uni SA cycling, Ken Wallace, Jimmy Owens, Elissa Phillips, Conny Draper, Bodhi Philpot, Arthur Fleury, Susan Horne, Dave Fox and Damian Farrow.