Demonstration on a Real-Time Vital Signs Monitoring System for Men during Exercise

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I. WHAT WE ARE

We, proposers, are a professor and a Ph.D. student of the Graduate School of Engineering, Osaka City University, Osaka, Japan. In a two-year project financially supported by the Ministry of Internal Affairs and Communications (MIC) of Japan, we have developed a real-time vital signs monitoring system for men during exercise. Our (proposers) expertise is wireless communication and signal processing, and furthermore an academic researcher (MD, Ph.D.) in medicine, an academic researcher (Ph.D.) in sports physiology, and several industrial researchers (Ph.D.) in engineering have been involved in the project.

The purpose of the system is not only medical and healthcare management (injury and disease prevention) but also effective sport training based on scientific data for ordinal people and athletes.

Regarding the system, we have so far presented the outcome of the project in several international conferences:

[1] S. Hara et al., "Development of a real-time vital data collection system from players during a football game," Proc. IEEE Healthcom 2013, pp. 387-391, Lisbon, Portugal, Oct. 2013.

[2] S. Okamoto et al., "Design of wireless waist-mounted vital sensor node for athletes - Performance evaluation of microcontrollers suitable for signal processing of ECG signal at waist part -," Proc. IEEE BioWireleSS 2014, pp. 16-18, Newport Beach, USA, Jan. 2014.

[3] T. Shimazaki and S. Hara, "Cancellation of Motion Artifact Induced by Exercise for PPG-Based Heart Rate Sensing," Proc. IEEE EMBC 2014, in CD-ROM, Chicago, USA, Aug. 2014.

[4] S. Hara et al., "Elements of a real-time vital signs collection system for players during a football game," Proc. IEEE Healthcom 2014, in CD-ROM, Natal, Brazil, Oct. 2014.

II. DETAILS ON THE DEMONSTRATION

The real-time vital signs monitoring system is composed of several wearable vital sensor nodes, data collection nodes (palm-top PCs) and a sink node (a note PC, namely, a monitor). The technical features of the system are as follows:

(1) Just putting a single wearable vital sensor node to the back waist position of a man/woman, we can monitor his/her heart rate (HR), energy expenditure (EE) and body temperature (BT), even when he/she makes vigorous exercise, such as running, sprint and jumping.

(2) To enable HR monitoring during vigorous exercise, we have developed a novel motion artifact cancellation technique for photo-plethysmo-graphy (PPG). We will explain the principle in the demonstration, and we could say this is the unique technique over the world which makes it possible at present.

(3) The system can monitor at a note PC the vital signs from many men/women (roughly up to 30) at the same time, in real-time, periodically and reliably, just using a single carrier frequency for wireless data transmission.

(4) The system can monitor the vital signs even when the men/women are spread in a large field (100mx150m).

(5) A system handler, a technical trainer for example, can easily check several healthcare, physical and physiological conditions (data) for all the men/women at the display of the note PC, such as current HR, EE and BT values and their histories.

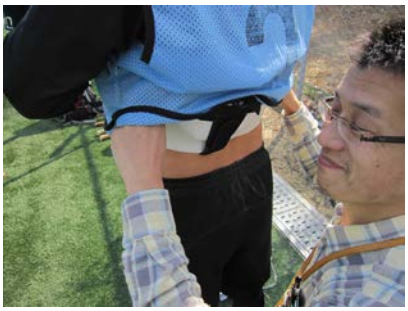
Fig. 1 shows the detail on the real-time vital signs monitoring system and photos of a field experiment (see [4] in more detail). In field experiments for football players, we put vital sensor nodes to twenty two players (a), and their vital signs were successfully monitored during a 90 minute-football game in real-time and periodically (c). The photo of the vital sensor node is shown in (b). In (d), a researcher of the project is explaining meanings of the items in the display and how to use the monitor system, and an example of the display is shown in (e).

The vital sensor nodes are still prototype, so unfortunately, they are a bit large. However, we believe the time can solve the problem of size and the developed technology is the most important.

In the demonstration, we will show several prototype vital sensor nodes and a note PC (monitor). We will not use data collection nodes which act as relays, so the vital sensor nodes will be directly connected to the note PC.

III. DETAILS ON THE DEMO EXPERIENCE

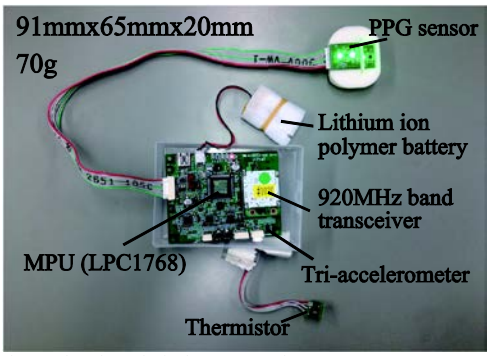
First of all, we believe it essential to show that the vital sensor node can correctly sense HR even during vigorous exercise. Therefore, in the demonstration, we, demonstrators, will have worn vital sensor nodes in advance and make several exercise such as running and jumping. Visitors will be able to understand the system correctly works by watching the displayer of the note PC. We will prepare several extra vital sensor nodes, so any visitor will be able to wear one of the vital sensor node if he/she likes, and he/she will be able to monitor his/her own HR during exercise. Motion artifact is a severe problem in PPG-based HR monitoring, and to cancel it, we have developed a novel



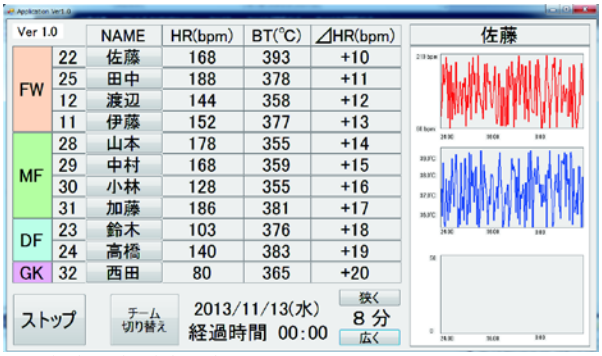
(a) Attaching a vital sensor node to a player

(c) A field experiment (football game)

(d) Real-time vital sign monitoring



(b) A developed vital sensor node



(e) Display of a sink node (note PC)

Fig. 1 Detail on the developed system and photos of field experiment.

technique and it is really applied in the demonstration system. Therefore, besides an oral or poster explanation on the principle, to understand how effectively the motion artifact canceller works, we will show the HR temporal variation graphs in the display by the developed canceller and a conventional band-pass-filter (BPF) technique. Visitor and audience will be able to really understand that, using our developed technique, HR sensing is possible at the waist position of a man, and motion artifact can be cancelled even during vigorous exercise.

Secondly, we will show that the system can collect and monitor the HR, EE and BT from many people at a display. In the demonstration, visitor will be able to watch the HR, EE and BT temporal variations from two demonstrators in the display. Of course, any visitor can wear a vital sensor node, so he/she will be able to enjoy watching his/her own temporal HR, EE and BT variations in the display. We have developed a novel technique for the EE calculation by means of tri-acceleration data, so we will explain its principle orally or by a poster.

Finally, we will show that the system can collect and monitor the vital data from people spread in a large field, however, frankly speaking, this demonstration may have a problem. Our system uses the 920 MHz band based on the IEEE 802.15.4g standard where the transmission power of transceiver is allowed to be 20 mW in Japan, resulting in longer transmissible range and higher invulnerability against blocking and shadowing. However, the use of the frequency band is not allowed in Brazil, so we need to use a suitable frequency band and transceivers which are compliant to the Brazilian radio regulation. Among commercial products of RF transceivers, we found the Xbee-wifi transceiver module legally (ANATEL) usable in Brazil, but unfortunately, the operating frequency band is the 2.4 GHz Industrial, Scientific and Medical (ISM) band, which has short transmittable range and vulnerability of blocking and fading. We decided to develop the demonstration system for HealthCom 2014 using the Xbee-wifi transceiver modules, and at present, we are not sure how far vital sensor nodes can be from the note PC keeping a wireless transmission reliability. But anyway, we do our best.

In global market, there are several products saying that they can collect and monitor vital signs in real-time from people during exercise. However, some say so only in their catalogs and others need to put electro-cardio-graphy (ECG) electrodes close to the heart, which is often prohibitive in types of sports. In addition, they use mainly the 2.4 GHz ISM band giving shorter transmittable range. We have successfully demonstrated our system in meetings and exhibitions held in Japan, so we can guarantee its workability even in Brazil. We have tried to improve our system by feeding-back audience's and visitors' questions and comments, so we are sure that our demonstration will be enjoyable.

Brazil is a country of football, so it is meaningful for us to demonstrate our system, which must be beneficial for footballers, coaches, technical trainers and physical trainers of amateur and professional clubs.

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