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Recording and Analysis of Biosignals on Mobile Devices

Introduction

Recording and analysis of biosignals is very important for healthcare and sports. The collected biosignals include electrophysiological signals like electrocardiogram (ECG) or electromyogram (EMG) as well as kinematics and kinetics. They are used to ensure correct execution of exercises, to assess the physiological state of athletes and to monitor training progress (Armstrong 2007). However, systems for data collection are expensive and often restricted to hospitals or biomechanics labs. Additionally, often an offline-analysis is performed, i.e. no feedback is available in the field and data must be processed on a separate PC. This is a huge drawback as immediate feedback about performance is desired by athletes and trainers.

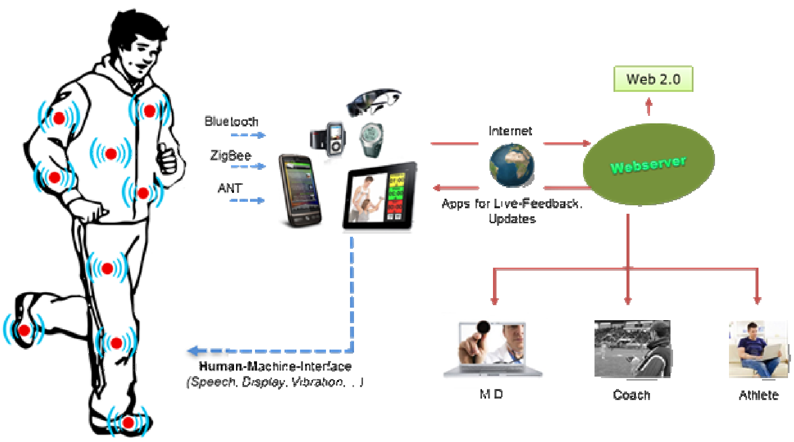

Fig.1: Mobile devices play a central role in Body Sensor Networks for sport and healthcare applications.

Recent approaches for this task include Body Area Networks (Figure 1). They consist of small wireless sensor nodes worn at the body. Examples are SHIMMER™, CodeBlue, Mercury, MobiHealth and MIThril (Chen et al. 2011). Applications include feedback training (Kugler et al. 2010), (Jensen et al. 2011), the physiological state of athletes (Eskofier et al. 2012) or movement disorders like Parkinson's disease (Barth et al. 2011). In the sport domain there is a trend to personal monitoring, where even casual athletes use systems like the adidas miCoach, Nike+ or Garmin Forerunner. Another example is the adidas_1 running shoe which continually monitors the current surface condition and adapts the cushioning of the sole (Eskofier et al. 2009). However, such systems are closed and perform only simple analysis. Mobile devices like smartphones or tablets are only used as user interface. However, in the future the growing processing power of these devices could be used to directly analyze the data. Hence there is a growing need for solutions to record and analyze signals in real time on mobile devices.

The purpose of this work is to present our approach to mobile recording and analysis of biosignals using body sensor networks and mobile devices. We show how SHIMMER™ sensor nodes can be combined with our ANDROID™ mobile sensor framework and demonstrate the applicability with example applications.

Methods

A working system for real-time analysis of biosignals consists of three major components: wireless sensor nodes, a mobile device receiving and processing the sensor data and the actual application running on the device. It provides the analysis algorithms and the user interface. In the following we present the sensor nodes, the mobile sensor framework on the device and some example applications.

Sensor Nodes To implement a usable and practical recording and analysis platform for healthcare and sport applications, we chose hardware from the off-the-shelf mobile sensor platform SHIMMER™ (McGrath et al. 2009). It was chosen as the nodes are small and light, commercially available and support a variety of physiological and kinematic sensors. They employ a low-power microcontroller, a lithium-ion battery and a wireless module supporting Bluetooth. Each node integrates a 3-D accelerometer and supports a large variety of plug-in modules for physiological (EMG, ECG, GSR), kinematic (gyroscope, magnetometer) or other sensors.

Mobile Sensor Framework After data is collected using the sensor nodes it must be transmitted to a mobile device. For the example applications the ANDROID platform was used. It is a widely supported open platform running on many phones and provides direct access to Bluetooth capabilities, simplifying wireless data transmission. To support rapid developing of example applications, we recently developed a mobile sensor framework (Kugler et al. 2011), see Figure 2. This allows easy access to data from various mobile sensors, e.g. ECG, EMG or kinematics.

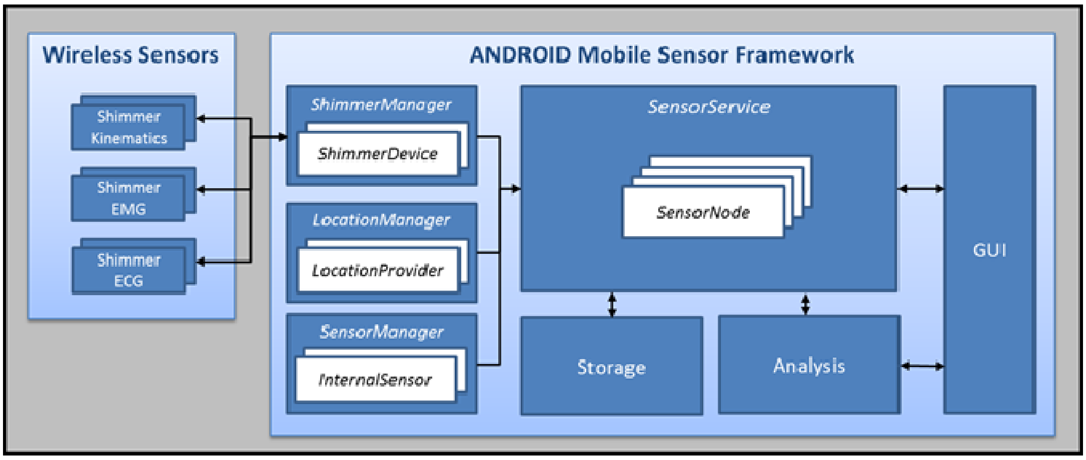

Fig.2: The modular software architecture of the ANDROID mobile sensor framework.

Example Applications To demonstrate our approach, a series of example applications was created. The first is a simple display and recording application (Figure 3 left). It was successfully used to record physiological and kinematic data during running studies (Kugler et al. 2011) and is still in use to collect kinematic data for the development of new applications (Kugler et al. 2012). The second example is a real time version of an algorithm which computes the knee joint angle from two kinematic sensors (Kugler et al. 2010), allowing a live display of the joint angle to the subject performing an exercise (Figure 3 middle). It demonstrates live feedback during exercises, which can support the correct execution of exercises like deep squats (Kugler et al. 2010). Another example application which was recently published (Jensen et al. 2011) is the mobile golf putting coach (Figure 3 right). It uses a sensor mounted on the club head to provide coaching advices after each put. The next application (Figure 4 left) demonstrates how arrhythmias in the ECG signal can be detected in real time on mobile devices (Gradl et al. 2012). A further application (Figure 4 right) computes the heart rate, RR-intervals, Poincaré plots (Mourot et al. 2004) and Lomb-Scargle periodograms (Lomb 1967), which are important fatigue indicators during endurance sports (Pichot et al. 2004), (Eskofier et al. 2012).

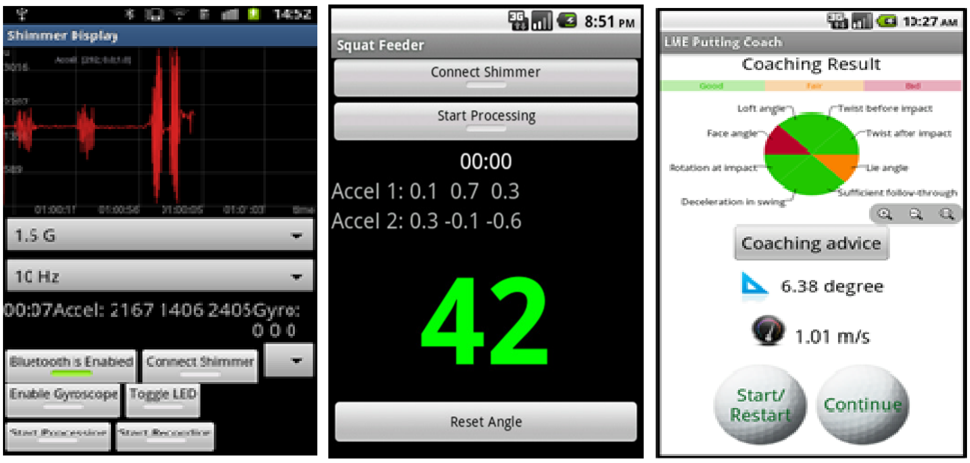

Fig.3: Example applications for kinematic recording and analysis. Left: live display and recording of kinematic signals; middle: automatic calculation of joint angles for feedback training; right: golf putting coach.

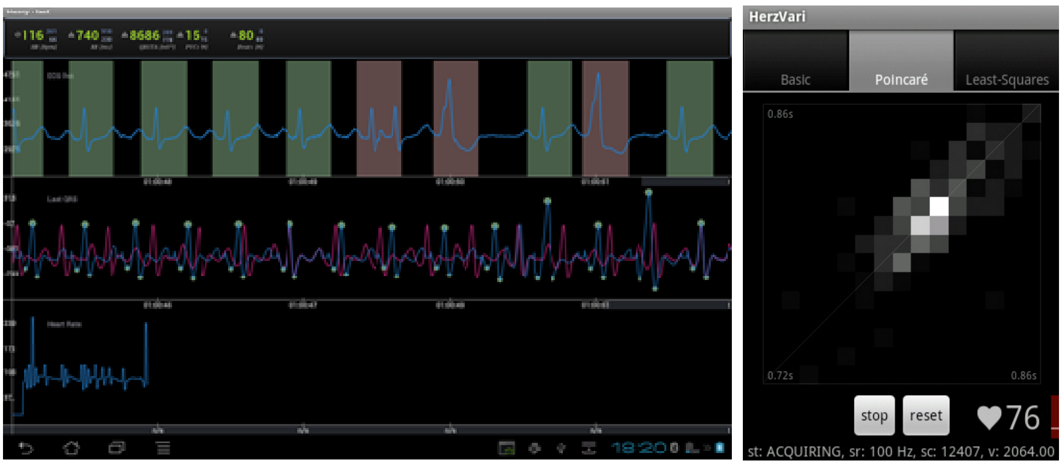

Fig.4: Example applications for the analysis of ECG-signals. Left: automatic QRS detection and arrhythmia classification; Right: computation of RR-Interval, Poincaré plot and Lomb-Scargle periodogram.

Summary and Outlook

In this work we presented our approach to provide real time analysis of biosignals on mobile devices. We showed the wireless sensor nodes, the ANDROID mobile sensor framework as well as some example applications. In the future such systems will allow athletes to use mobile devices for feedback training or to monitor their physiological parameters to optimize training procedures.

Acknowledgment

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References

Armstrong S. (2007). Wireless connectivity for health and sports monitoring: a review. British Journal of Sports Medicine, 41, 285-289.

Chen, M., Gonzalez, S., Vasilakos, A., Cao, H. & Leung, V. (2011). Body area networks: a survey. Mobile Netw. Appl., 2 (16) 171-193.

Kugler, P., Jensen, U., Eskofier, B. & Hornegger, J. (2010). Feedback-Training mit tragbaren Sensor-Netzwerken. In Proc. of the INFORMATIK 2010, Band 1, Leipzig, 3-8.

Eskofier, B. M., Hoenig F. & Kuehner, P. (2008). Classification of perceived running fatigue in digital sports. In Proc. of the ICPR 2008, 1-4.

Barth, J, Klucken, J., Kugler, P., Kammerer, T., Steidl, R., Winkler, J., Hornegger, J. & Eskofier, B. (2011). Biometric and Mobile Gait Analysis for Early Detection and Therapy Monitoring in Parkinson's Disease. In Proc. of the EMBC 2011, Boston, 868-871.

Eskofier, B., Kugler, P., Melzer, D. & Kuehner P. (2012). Embedded Classification of the Perceived Fatigue State of Runners - Towards a Body Sensor Network for Assessing the Fatigue State during Running. In Proc. of the BSN 2012, London.

McGrath, M. & Dishongh, T. (2009). A Common Personal Health Research Platform — SHIMMER™ and BioMOBIUS™. Intel Technology Journal, 13 (3), 122–147.

Kugler, P., Schuldhaus, D., Jensen, U. & Eskofier, B. (2011). Mobile Recording System for Sport Applications. In Proc. of the IACSS 2011, Shanghai, 67–70.

Kugler, P., Schlarb, H., Blinn, J., Picard, A. & Eskofier, B. (2012). A Wireless Trigger for Synchronization of Wearable Sensors to External Systems during Recording of Human Gait. In Proc. of the EMBC 2012, (accepted).

Jensen, U., Kugler, P., Dassler, F. & Eskofier, B. (2011). Sensor-based Instant Golf Putt Feedback. In Proc. of the IACSS 2011, Shanghai, 49–53.

Eskofier, B, Oleson, M., DiBenedetto, C. & Hornegger, J. (2009). Embedded Surface Classification in Digital Sports. Pattern Recognition Letters, 30 (16), 1448–1456.

Gradl, S., Kugler, P., Lohmüller, C. & Eskofier, B. (2012). Real-time ECG monitoring and arrhythmia detection using Android-based mobile devices. In Proc. of the EMBC 2012 (accepted).

Mourot, L. et al. (2004). Decrease in heart rate variability with overtraining: assessment by the Poincaré plot analysis. Clin. Physiol. Funct. Imaging. 24(1),10-8.

Lomb, N. R. (1976). Least-squares frequency analysis of unequally spaced data. Astrophysics and Space Science, 2(39), 447-462.

Pichot, V. et al. (2000). Relation between heart rate variability and training load in middle-distance runners. Med. & Sci. in Sports & Exerc., 10(32), 1729-1736.