ConText: Contactless Sensors For Body Monitoring Incorporated In Textiles

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***Abstract*— The aim of the ConText project is to develop a vest with integrated sensors and electronics for constant monitoring of muscle activity. The vest measures muscle activity in order to derive the psychological stress level of a person. The ConText project proposes to develop a sensor technology, which requires no direct contact with the body, and to achieve a high level of integration of the sensors and electronics into textile. The realisation of contactless EMG sensors, textile integration of the sensors and the creation of a textile substrate with conductive wiring for data transmission and power supply will be the important parts of the project. The prototype will be used for dissemination and application development.**

I. Introduction

The healthcare market is currently subject to a structural change. Healthcare expenditures are currently focused on professional consultancy after an individual has become ill. This is an expensive system due to the high costs of medical examinations, interventions and hospital beds. One solution to reduce the healthcare costs is to put our efforts on the pre-intervention chain from health management, prevention, self-diagnosis to home monitoring. The technologies to enable this are gathered under the personalised health and electronic health monitoring concepts: pHealth and eHealth. The customer buying health monitoring tools is no longer solely the professional but becomes more and more the individual patient. The World Health Organisation requires that every country develops a pHealth strategy within four years [1].

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An excellent embodiment of a health monitoring device is a wearable system, for example a health awareness system in cloths. Cloths are natural possessions and are part of the processes and routines in our daily life. The technological drive is to integrate sensors and electronics in textiles in such a way that the usage and advantages of cloths are maintained. A high level of textile integration has to be combined with aspects of reliability, comfort and wash resistance.

Sensors suitable for integration in clothes should be non-invasive and must be capable of monitoring health and wellness parameters. The common approach is to take relatively simple measuring techniques and to use signal processing and multi-parameter analysis to derive the physiological parameters of interest. In the ConText project, the universal measurement method of surface electromyography (sEMG) is used from which information about fatigue is derived by signal processing. Interpretation of the sEMG signal may be assisted by electrocardiography (ECG) signals and the output of movement/position sensors. Nevertheless, the focus is on electromyography because a technological drive of the project is the research on contactless EMG sensors. Contactless sensors strengthen the advantage of textile integration because they enable maintenance of the normal way of using clothes.

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II. SMART FABRICS AND INTERACTIVE TEXTILES CLUSTER

The European commission adopted the concept of smart clothing applied to personal health monitoring. Therefore, they support several projects combining pHealth and electronic textiles [2].

The MyHeart project [3] realised a respiratory and ECG monitoring bra. Recently the project entered the implementation phase where four focal areas are chosen. Still, realisation of the applications in textiles is considered.

The BIOTEX project [4] aims at developing dedicated biochemical sensing techniques compatible with integration into textile. Instrumented clothes will provide remote monitoring of vitals signs, diagnostics to improve early illness detection of metabolic disorders. The textile integrated sensors will be monitoring body fluids.

In the ProeTEX project [5] the applications are textile and fibre based integrated smart wearables for emergency disaster intervention personnel with a goal of improving their safety, coordination and efficiency and additional systems for injured civilians aimed at optimising their survival management.

In the STELLA project [6], develops stretchable electronics for large area applications for use in healthcare, wellness and functional clothes, integrated electronics in stretchable parts and products.

The aim of OFSETH [7] is the integration of the optical fibres related technology into functional textiles to extend the capabilities of wearable solutions for health monitoring. This project represents a new challenge : the possibility of realising wearable optical devices for monitoring the health parameters of patients. By including optical sensors we may expect an extension of the number of assessable vital parameters.

The main output of MERMOTH [8] is a comfortable, wearable monitoring prototype unit, based on a "wearable interface": it is implemented by integrating smart sensors, advanced signal processing techniques and new telecommunication systems on a textile platform. A parallel data management provides the first two markets with a whole prototype unit for extensive testing.

The differentiating factors of the ConText project [9] are in the application to stress and musculoskeletal disorders, the contactless EMG sensors and the usage of weaving versus knitting for the textile substrate [10], [11].

III. MUSCULOSKELETAL DISORDERS

Work related musculoskeletal disorders occur when there is a mismatch between the physical requirements of the job and the physical capacity of the human body. Many different work-related musculoskeletal disorders originate from repetitive motion, heavy lifting, forceful exertion, contact stress, vibration and bad posture. The problem is noticed by the European Commission and reported in two memo's [12], [13] Work related musculoskeletal disorders (mainly back pain and repetitive strain injury) are the biggest health and safety problem amongst European workers today. Over 40 million workers in all sectors are affected. They are responsible for forty to fifty percent of all work-related ill-health and lead to losses of 0.5 to 2% of GNP per year. The EU advisory committee on safety, hygiene and health protection at work emphasizes that a number of measures should be taken to enable successful prevention of musculoskeletal disorders for European workers. One of the named measures is appropriate medical management, including the promotion of the reporting and identification of early symptoms and the onset of musculoskeletal disorders, prompt treatment and proper rehabilitation.

The ConText project proposes a tool which can be used for continuous monitoring and that can give specific feedback about increasing muscle tension to workers at risk and/or patients suffering from work related musculoskeletal disorders. Tools like this will play an important role in prevention, diagnosis and treatment of musculoskeletal disorders.

IV. CONTACTLESS ELECTRODES FOR ELECTROMYOGRAPHY

All living cells are surrounded by membranes. These membranes are selectively permeable for various ions and may actively transport them through the membrane resulting into a membrane potential. Nerve cells and muscle fibres are depolarised when activated by a certain threshold voltage. The result is the propagation of a depolarisation wave along the nerve and muscle fibre [14]. A depolarisation wave over the muscle fibre is the direct cause of muscular contraction and is subsequently followed by relaxation. The quick combination of contraction and relaxation of a muscle fibre is referred to as "twitch". Since all muscle fibres in a muscle do not twitch simultaneously, the overall observed potential over a muscle is the random summation of multiple single fibre action potentials. This random signal is conducted to the surface of the skin by means of volume conduction.

With surface electromyography (sEMG) electrodes are placed on the skin in order to record the muscle potentials. A common configuration is a set-up of two electrodes along a muscle contacting the skin using conductive gel. A problem with this set-up is that the interface potential between the skin and the solid electrode is undefined. In addition, it is uncomfortable to tape such electrodes onto the skin. Therefore, contactless electrodes are proposed in literature to monitor signals of the heart [15-17], which is also a muscle. These electrodes detect an electric displacement current by coupling capacitively to the body instead of detecting a Nernstian current; therefore, they require no electrical contact with the skin. The possibility to avoid direct skin contact reduces the skin irritations problems.

Fig. 1 shows the bipolar set-up with two contactless electrodes with which the first EMG experiments are successfully performed. The electrodes are not yet integrated into textile, but consist of 12 mm circular shapes on a printed circuit board. Because of the capacitive coupling, the impedance of the sensor is extremely high. The result is that environmental noise is easily picked up. This problem is solved by placing an impedance converter directly on top of the electrode. The electrode is actively shielded by feeding back the output signal of the local amplifier to a metal cap over the electrode. The individual sensor output signals are fed into an analog to digital converter after anti-aliasing filtering. All signal processing is done in the digital domain.

Because the AD conversion is done with a card in a grounded desktop PC, the largest noise is the 50 Hz which is capacitively coupled from the environment to the human body. With the first experiments, the person under test is grounded in order to reduce this 50 Hz noise.

Fig. 2 shows the measured EMG signal on the biceps while lifting a weight of 2.5 kg with a 90 degrees bended arm. The contactless sensors have an electrode spacing of 37 mm and a gain of 11. It is compared to a commercial active sEMG electrode (B&L Engineering type BL-AE-N) having a spacing of 20.6 mm and a gain of 346. In Fig. 2, the signals are normalised by the gains to give the skin surface voltage. Note that it is not possible to perform the two recordings simultaneously.

In Fig. 3, the spectra are shown for the two measurement methods using the same data set as in Fig. 2. As a reference,

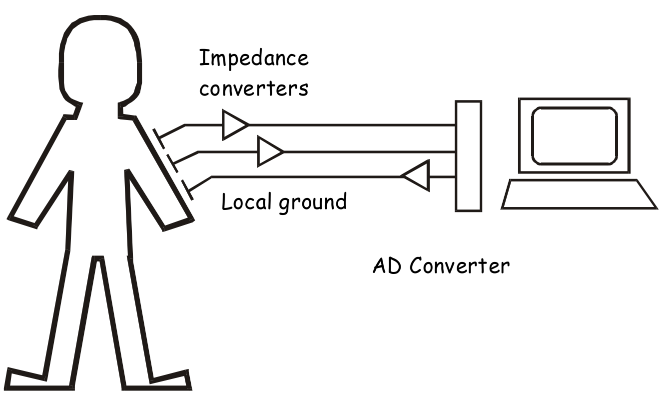

Fig. 1.: Set-up for contactless sensing EMG signals

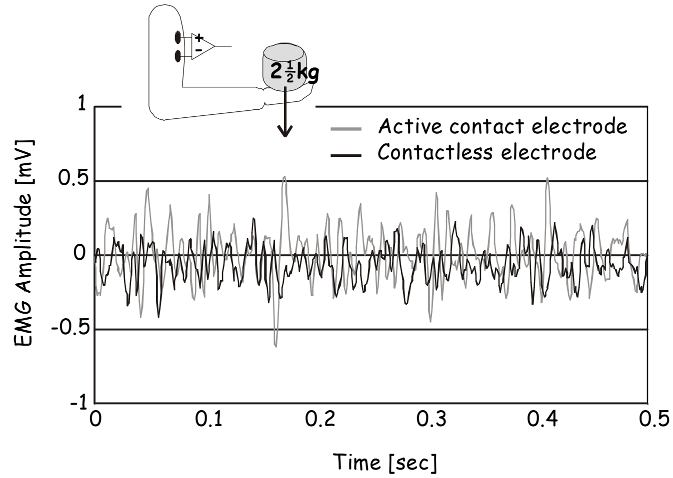

Fig. 2: Recorded EMG signals with both an active- and contactless electrode

the spectra during rest are plotted as well. We can see that the contactless electrodes and the commercial active sEMG electrodes provide similar signal levels and shapes. Only the bottom noise during rest is a little bit higher. The bandwidth of the contactless electrode set-up is adequate and comparable to the reference measurement.

V. THE CONTEXT PROJECT

The ConText project started in January 2006 and will last for two and a half year. The final aim is a fully functioning prototype of a stress monitoring vest. In this scenario sketch of Fig. 4, a tiler gets feedback on his posture during work. With this feedback he is able to minimise the risk of lower back pain and stress induced by inefficient muscle contractions in the neck area.

The focus is on the following topics:

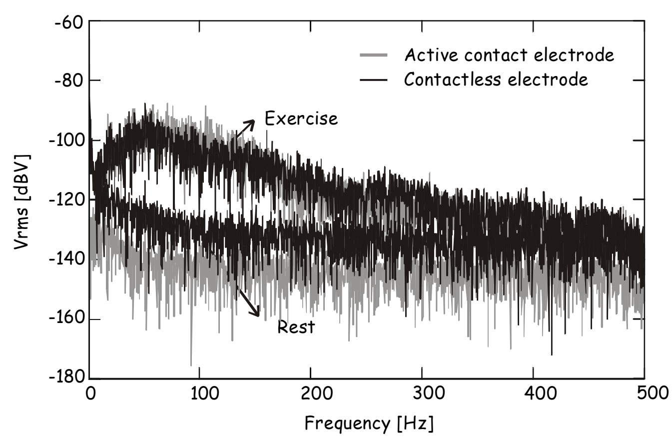

Fig. 3: Spectra of the recorded EMG signals with both an active- and contactless electrode

Fig. 4: Application scenario for the ConText vest [Courtesy: TNO]

- Integration of the contactless electrodes into textile
- Use sensor arrays or other techniques to compensate for motion artefacts
- Develop technology for robust interconnect of the impedance converter with the textile electrodes
- Make a shirt with textile interconnect using woven power and signal lines
- Implement algorithms for deducing clues for fatigue and stress from the EMG signals
- Although the main focus is on EMG, accelerometers, ECG and/or respiratory sensors may be integrated depending on the requirements of the stress algorithm

Besides the development of the shirt itself and the corresponding technological challenges, an application case will be considered as well. Stress and fatigue monitoring can be adopted for many applications. It is part of the project to select one of the potential applications and to evaluate the value of the business model. To do this, an application forum will be formed with parties outside the ConText consortium. The project website www.context-project.org facilitates the formation of such an application forum.

VI. The ConText Partners

The ConText consortium contains 6 partners and is a combination of industrial companies and institutes with world-class knowledge of sensors and electronics, textiles and musculoskeletal disorders. The contribution of Philips (the Netherlands) is in electronics hardware and data processing, as well as project management. The Katholieke Universiteit Leuven (Belgium) will determine the textile sensor characteristics and will create algorithms that can link the muscle activity measurements to the psychological stress state. Technische Universität Berlin (Germany), TNO (the Netherlands) and TITV (Germany) each have their own expertise in electronic textile integration, such as modification of pre-metallised textile thread materials, weaving and embroidery of conductive yarns and printing of conductive structures onto textiles. Clothing+ (Finland) has the knowledge on the application and market opportunities for electronic textiles.

VII. Conclusion

In the ConText project the expertise and skills of six partners are combined to develop a muscle activity monitoring vest. The vest anticipates to a set of work related diseases, which are an increasing financial burden to our society. To exploit the natural usage of clothes, contactless EMG sensors are chosen. A direct consequence is that pre-amplifiers have to be mounted directly on the textile sensors. This results in the need for advanced interconnect technologies for textile integration.

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