Interactive wearable feedback system

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***Abstract*—In this abstract we present our work towards an interactive wearable multi-modal sensor/biofeedback system for mission critical activity training and monitoring. The goal of this ongoin work is to develop an innovative wearable system, that can sense the actions taken by a person during mission critical activities and provide a timely and useful feedback in order to improve both the efficiency and safety of performing these tasks.**

***Keywords*—Wearable system, feedback, wearable sensors**

I. Introduction

Wearable sensor systems are becoming more and more commonplace, and can include such solutions as IMU based motion capture [1], monitoring of vital signs such as temperature, pulse, muscle activity [2], and even monitoring of external environment [3]. As such, if integrated in easy to use clothing and accompanied with sufficiently effective wearable feedback, such technologies have great potential for helping people in performing or learning complex mission critical activities. In this ongoing work we are exploring the potential benefits of such integration, and discuss ongoing implementation of our experimental system for developing such technologies.

II. Concept

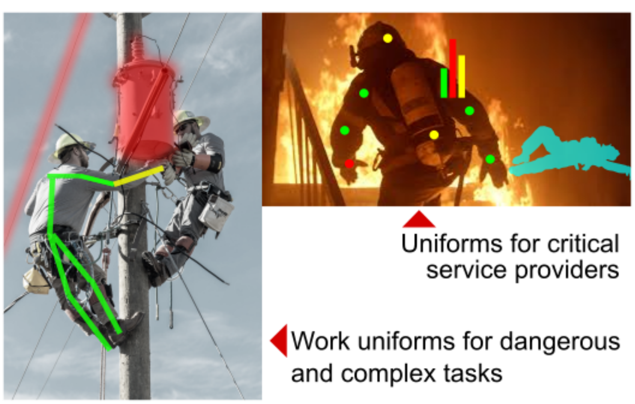

Fig. 1. Illustrations of potential usecases in danger prevention

During our research we have identified several industry driven use-cases where such wearable feedback technologies could be useful. Through discussion of companies interested in such solutions, some common requirements emerged, that the technology should provide in order to be useful:

Danger prevention: Workers in critical tasks, such as electricians or firefighters often have to perform their tasks in complex and dangerous conditions. In order to succeed, they must be protected both from short term and long term dangers including overheating, electrical shock or hearing loss due to prolonged noise exposure. Thus a wearable feedback system must not only warn or actively prevent dangerous accidents, but also limit and log exposure to potential loing term dangers, such as vibrations, noise etc. Additionally, when working in teams, it is often important to track multiple team members and warn others if one of them requires help. Some of these concepts are illustrated in Figure 1.

Fatigue detection: All interested companies we identified, emphasized the importance of timely fatigue detection, as this can reduce injury risks and prevent sub-par work outputs and/or damaged equipment due to fatigued workers being more error-prone.

Muscle fatigue is a common symptom characterized by tiredness, lack of energy, and exhaustion. It is linked to difficulties in voluntary movement. Different factors, such as muscle contraction strength and activity type, determine the involvement of motor units and muscle fibers. Fast-twitch fibers are used in intense, fast activities, while slow-twitch fibers are activated during prolonged, low-intensity exercises [4]. Muscle fatigue can be acute (short-lived and relieved by rest) or chronic (persists for months despite rest). It can also be categorized as mental or physical fatigue. Acute muscle fatigue is classified as central or peripheral. Central fatigue involves the central nervous system and affects nerve-to-muscle communication due to chemical imbalances in the brain. Peripheral fatigue occurs when signal transduction at the muscle level is hindered, resulting from factors like depleted energy stores, insufficient calcium ion release, oxygen deprivation, metabolite accumulation and mechanical stress [5].

Muscle fatigue can be studied and potentially detected thorugh different approaches: 1) changes in physiological processes (heart rate monitoring, infrared spectroscopy, measurement of gas exchange, blood lactate levels etc.), 2) changes in neuromuscular function (functional or maximal power tests, muscle electrical activity), 3) kinematic analysis (using motion capture technology), 4) patient self-assessment tests - RPE (Rate of Perceived Exertion) or VAS (Visual Analog Scale).

Help in complex skills: The third identified problem with potential to be solved by using wearable feedback systems

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is related to learning and executing complex skills. In tasks, where a person is required to follow non-trivial procedure, a timely feedback is critical to fast learning [6]. Thus a wearable system could detect if the task is executed correcly and provide real time feedback on how well the learner is doing. Additionally detection of correct execution of complex tasks is also useful after learning is complete in order to determine whether someone needs a refresher course or some specific factors lead employees to make mistakes in these critical tasks.

III. Implementation

The implementation plan is based on fully integrated [7] easy to use weatable sensor and feedback system based on our existing sensor clothing research [1] with additional added sensors both for monitoring the person themselves and the environment, as well as feedback actuators:

Sensor nodes: Multiple sensor nodes will be implemented in the wearable system. Each of them currently are planned to have the following schematic as shown in Figure 2, and will consist of these main sensors: motion (IMU), body temperature, pulse, sweating, muscle activity (EMG), breathing, blood oxygenation, noise (microphones), environmental temperature, air humidity, CO_2 and electrical field sensors.

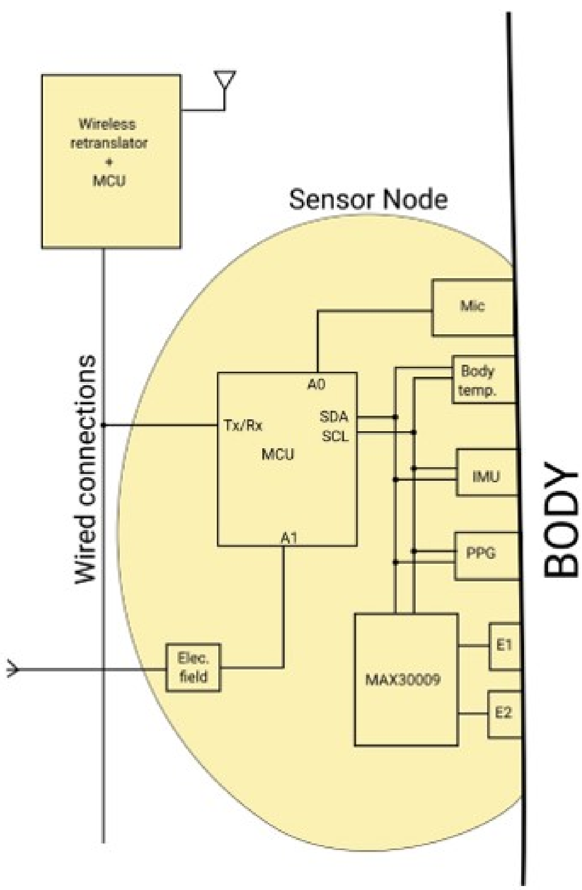

Fig. 2. Schematic of planned first version sensor node.

Electrical field sensing circuit: The selection of requirements for an electrical field sensing circuit is contingent upon its designated application. As an integral component of a wearable system, the circuit must possess a compact form factor and exhibit immunity to the electrical field emanating from the human body.

The solution shown in Figure 3 consists of an active 4-pole bandpass filter with central frequency of 50Hz and bandwidth of 20Hz. In order to prevent the detection of the electrical field originating from the human body, the ground pole should be connected to the body as a reference, while the entirety of the circuit, excluding the antenna, should be shielded. The antenna is a simple wire and the operating frequency is extremely low, and antenna length (L) is significantly smaller than wavelength (λ).

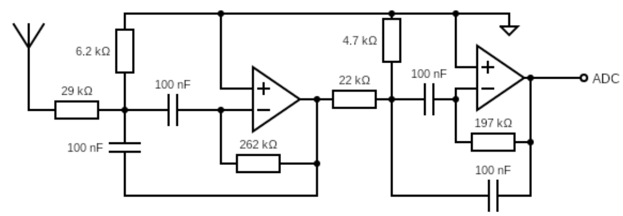

Fig. 3. Basic electrical field sensing circuit

Feedback: There are multiple possibilities for wearable feedback that are currently being explored. For complex real-time feedback especially promising seem to be sensory replacement through haptics [8], as this type of feedback could potentially be processed faster than vision and hearing, thus potentially preventing danger faster than visual or audio feedback.

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