Big Data & Wearable Sensors Ensuring Safety and Health @Work

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***Abstract*—Work-related injuries and disorders constitute a major burden and cost for employers, society in general and workers in particular. We@Work is a project that aims to develop an integrated solution for promoting and supporting a safe and healthy working life by combining wearable technologies, Big Data analytics, ergonomics, and information and communication technologies. The We@Work solution aims to support the worker and employer to ensure a healthy working life through pervasive monitoring for early warnings, prompt detection of capacity-loss and accurate risk assessments at workplace as well as self-management of a healthy working life. A multiservice platform will allow unobtrusive data collection at workplaces. Big Data analytics will provide real-time information useful to prevent work injuries and support healthy working life.**

Keywords-Preventive Occupational Healthcare; Ergonomics; Wellbeing at Work.

I. Introduction

Currently, work–related disorders yield a significant cost for society. In Europe, this cost has been estimated to range between 2.6 and 3.8% of gross national product (GNP) [1]. For Sweden, this cost has been calculated to more than 5 billion € annually. The economic impact for occupational stress in the USA exceeds 300 billion USD per year [2]. In addition to quality and productivity losses, a poorly designed workplace can generate a direct cost of over 50000 € for a single company.

Statistics indicate that human error is common in work accidents especially among heavy machinery operators and truck drivers. In 87% of truck accidents caused by the driver, the driver was not fit for driving due to fatigue or use of prescribed drugs [3]. Additionally, it has been shown that implementing health and wellbeing initiatives in companies may not only reduce work absenteeism with average of 25% but also decrease up to 40% workers compensation cost [4, 5]. Thus, there is a great need for solutions enabling prevention of occupational health-risks, preventing accidents in the operation of dangerous machineries, and also improving employee’s health and wellbeing at work. The rest of the paper is structured as follows. In Section 2, the main hypothesis of project is described. Project goals are described in section 3 and followed by introducing the consortium in section 4. Use case specification and system architecture are described in section 5 and 6, respectively. Finally concluding with a short summary.

II. Working Hypothesis

New technologies provide a basis for practical actions enabling opportunities to ensure a healthy and safe working life. Current rapid developments in sensor technology, mobile data acquisition, improved risk assessment methodologies combined with Big Data analysis allow the development of pervasive and unallocated solutions. We hypothesize that this combination can usually predict the risk at workplaces, the individual’s risk of developing work-related disorders and assess the capacity for operating demanding and dangerous machinery (including cranes trucks, buses, trains and airplanes) to a cost that is realistic for the main working environment actors and different stakeholders, *e.g. occupational health services.*

III. Project Goals

We@Work [6] aims to transform the current implementation of occupational health services achieving the following objectives:

A) To implement a service enabling self-management of health and wellbeing @work for employees.

B) To implement a service enabling screening for psycho-physical capacity to operate demanding equipment.

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C) To implement a service for early warning of risks for musculoskeletal disorders caused by adverse work design.

D) To develop such a scalable solution hosting the previous services to a pre-commercial development level.

IV. Consortium & Key Components

A multidisciplinary consortium involving seven partners from Spain, Netherlands and Sweden has been created:

- *Industry and Occupational Health Enterprise:* Atos Spain S.A. (project leader), Philips Research, Z-Health Technologies AB (Z-HT) and QuironPrevencion.
- *University Hospital and Academia:* Karolinska Institutet, KTH – Royal Institute of Technology, Karolinska University Hospital a part of Stockholm County Council.

Phillip's cloud platform combined with wearable monitoring technologies like garments sensorized with Z-HT's *ECGZ* monitors (see *Figure 2*), [5], inertial motion units and the Phillip's *Health watch*(see *Figure 1*), [7] will boost the potential impact of Atos' *Pocket mHealth* app for self-health assessment and QuironPrevencion's screening tool for predicting loss of psychophysical capabilities: the VAPEL system [8].

V. Use Case Specifications

In order to validate the different technological solutions developed in this project, two different scenarios have been selected as use cases. The main objective of these is to test the detection of detrimental changes in the workers, produced either by the working or the individual's conditions, by monitoring the variables acquired from the collection of sensor systems. If certain pre-established ranges are surpassed, which could indicate that a loss of the worker's capacity is occurring, immediate actions can be possibly taken to alleviate or avoid this circumstance.

Initially, a risk assessment of the health status of the worker will be carried out, making use of Goldberg's General Health Questionnaire [9]. If the health situation of the worker is especially complex, the platform will communicate it, avoiding sending messages and notifications that may entail a risk. The user could control the maximum amount of notifications to receive per day (except for some priority alarms related to health risks).

Figure 2: Textrode Sensorized Vest;(a) electrode placement in the inner side view (b) front view and monitoring device, (c) back view.

Figure 1: The Philips health watch.

Some thresholds for heart and respiratory rates could be included to send urgent warnings if these limits are surpassed. Following the acquisition of data from the sensor system, the analytic layer will request the data from Pocket mHealth for the further analysis, making use of stored health and monitoring data to offer recommendations, suggestions and advices being these displayed by Pocket mHealth. On the other hand, the worker could decide if they want to store some of the gathered data in his/her personal health record. The two different scenarios that are included in this use case specification are the following:

A. *Sterilizing Unit at a hospital*

The setting comprises a real working scenario with 12 employees at the new Karolinska University Hospital environment. These workers are exposed to repetitive movements, awkward postures and strenuous pushing and pulling efforts, in a situation of medium to high activity rate, with manual handling of medical instruments and three different work shifts in a 24-hour time-lapse. It is common to find musculoskeletal disorders in this scenario, especially pain in elbows and shoulders.

In the first stage, data is collected regarding the individual's basic parameters like age, gender, level of daily activity. After, the self-health assessment and VAPEL screening tool are used for monitoring any potential loss of capabilities. The VAPEL tool will be used several times during the day, typically 4 times.

Through the sensor system mentioned before, instant values of biomedical data are acquired. These monitored variables consist of the individual's heart rate, energy expenditure, postures and movements of upper arms, back and wrists, as well as the worker's physical activity (time in sitting / standing / walking / other activities).

Once these variables are stored in the system, algorithms developed by Karolinska Institutet and KTH Royal Institute of Technology (KTH) will be applied, in order to check if the values are inside pre-established ranges. If these ranges are surpassed, an alarm signal will be produced by the system, notifying the worker through the Pocket mHealth, he/she may inform his/her manager, and they may together search for solutions.

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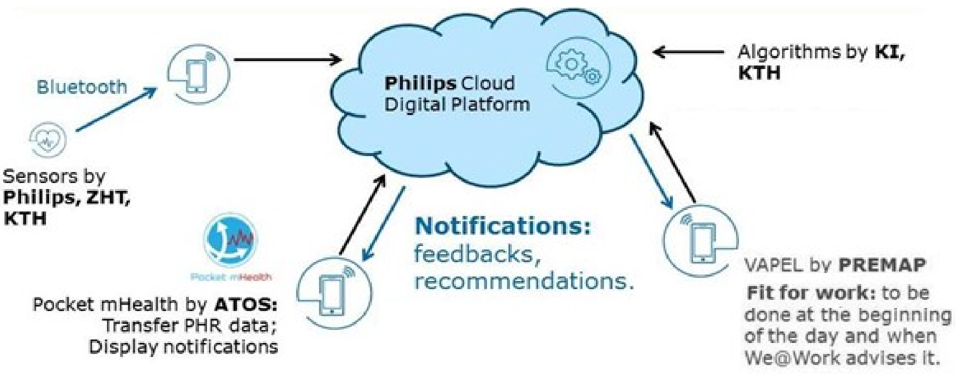

Figure 3: We@Work Architecture Framework

B. Wellbeing at the office

The setting is comprised of two different scenarios, located in Stockholm (KTH) and Madrid (Atos), accounting for a total of 24 workers and a time term of project of 2-4 weeks, in an office daily schedule.

In the context of white-collar workers and the office workplace, it is intended to validate the system as a tool to promote and support a healthy and safe working life, reducing the number of work incidences or occupational health problems.

We will make use of real-time data, ergonomic analysis and Pocket mHealth as the user interface, in order to provide notifications, recommendations and warnings to employees. The system will always provide clear and simple messages (feedback, suggestions and advises), avoiding any kind of misunderstanding.

Specifically for the Atos scenario, Premap will support in the identification of risky situations, measuring the variation of response times according to the time of the working day and the day of the week, by means of a mobile device type test. If a risky situation is identified, actions will be done to check if a loss of capability of the worker has been produced, including the realization of the VAPEL test.

VI. System Architecture

In order to structure how the We@Work innovation project will meet the goals defined by use cases, the architecture of the pervasive monitoring solution, see Figure 3, is described.

The We@Work platform consists of a cloud based infrastructure, wearable sensor units and mobile applications. The cloud based backend infrastructure will be developed by Philips and makes use of Amazon Web Services. Android applications by Atos, KTH, Philips and Premap will use the cloud platform for communication, storage, user management, potential big-data analysis and pushing notifications and feedbacks. Each application will have a specific functionality dedicated to data gathering from sensors through Bluetooth or other sources like questionnaires. The communication between sensing layer and cloud system is based on HTTPS protocol through representational state transfer (RESTful) application programming interface (APIs).

According to the use case specifications, the technologies included will be:

- Philips Health watch, a wrist-worn Bluetooth equipped wearable sensor that will allow keeping track of periods of physical activity. This data is synced to a backend system where it can be used for further processing to generate specific outputs for the defined use cases.
- Z-Health ECGZ and garment, which allow the sensing of biopotentials and electrical bioimpedance. Together with a vest or underwear t-shirt equipped with textile electrodes on the chest it is possible to obtain an ECG LEAD II that allows an uncomplicated detection of the R-peak and straightforward extraction of heart rate, enabling heart rate variability analysis.
- Inertial measurement units, in addition to built-in accelerometers Philips Health Watch, with 3-axis accelerometer, 3-axis gyroscope and 3-axis magnetometer that will be used to measure the exposure of different limbs e.g., arm, shoulder, wrist and/or activity recognition.
- Pocket mHealth, as the main component for the communication with users of We@Work. It will display visualization of relevant data from the user, including reception of the notifications generated by the analysis components based on the data collected from the use, and will serve as a possible source of data collected from the users.
- Analytics algorithms (KTH), to provide workers with feedback, advice and suggestions to health and wellbeing, with the pre-establishment of ranges and decision rules to enable alarms and recommendations. For physical workloads, these will be based on energy expenditure while for repetitive movements and uncomfortable postures this will control relative angles and angular velocity. Physical activities are also evaluated with time sitting / standing / walking. The parameters will be presented on the platform allowing for feedback. Warnings will be triggered when the signals exceed the recommended limits accordingly. The warnings can be shown as notifications on the platform (Pocket mHealth), including both visual and auditory forms.

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- Cloud computing platform, to request/send data from/to the data backend, store data and run analytics. The result of these analyses will be stored in the database by using a custom API. In case of need for a feedback, notifications will be generated through notification system APIs.
- VAPEL, to assess the psychophysical capacity of workers (sufficient or not), through a series of tests that value the basic executive functions. The aim of VAPEL is to get a new system, which is able to assess and measure psychophysical skills of workers in order to ensure a safety workplace.

The system must be secured by providing confidentiality, integrity and availability and must implement basic security behaviors, such as authentication, authorization, confidentiality and data integrity.

CONCLUSION

We@Work project aims to integrate unique and currently available technological systems to obtain a completely integrated information communication technology (ICT) platform for occupational health. The platform will be validated during 2018 in real work scenarios at Karolinska University Hospital as well as within other partners associated with the consortium directly or indirectly.

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