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Architecture for Integrated Real-Time Health Monitoring using Wireless/Mobile Devices

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***Abstract:** This research is to propose an applicable framework for real-time health surveillance and safety monitoring at construction sites. First this study aims at finding (1) a framework for health surveillance that is likely to benefit employers and employees in the industry, (2) a valid way to identify factors or conditions with potential health concerns that can occur under particular work conditions, (3) An effective way to apply wireless/mobile sensors to construction workers using real-time/live data transmission methods, and (4) A relationship between a worker's vital signs and job site environment. Biosensors for physiological response and devices for weather/work related data are to collect real-time data. Relationships between jobs and physiological responses are analyzed and factors that touched particularly contributing to certain responses are identified. When data are incorporated with tasks, factors affecting tasks can be identified to estimate the magnitude of the factors. By comparing work and normal responses possible precautionary actions can be considered. In addition, the study would be lead to improving (1) trade-specific dynamic work schedules for workers which would be based on various factors affecting worker health level and (2) reevaluating worker productivity with health status and work schedule, thereby seeking ways to maximize worker productivity. Through a study, the paper presents expected benefits of implementing health monitoring.*

***Keywords:** Biosensor, Health Surveillance, Physiological Responses, Real-Time Data Tracking, Automated Preventive Warning*

I. INTRODUCTION

A. *Work-related Fatality in Construction*

The construction industry is an industry with a high number of fatalities. Construction workers suffered 21 percent of the nation's work-related deaths in 2003 alone [1]. As Fig. 1 indicates, the construction industry has the highest number of fatal injuries. In 2002, the total costs of fatal and nonfatal injuries in the construction industry were estimated to be over $11 billion [2].

The number of heat-related fatalities is expected to increase, due to increasing heat and humidity [3]. Studies have shown that workers also feel more fatigue and stress in the construction industry compared to other industries. This fatigue eventually affects the productivity of construction workers [4]. According to Davis et al., not only job site conditions but also individual health is a significant factor affecting workers' safety [3][4][5].

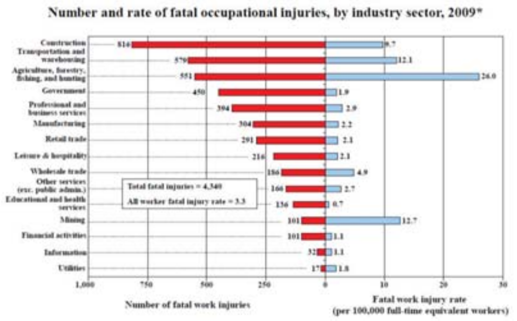

Figure 1. Number and rate of fatal occupational injuries, by industry sector [6]

B. *Current Issues and Proposed Approach*

A tight work schedule as well as constant exposure to changing weather (air temperature, humidity, or wind), noise, vibration, or odor increases the level of fatigue and stress [7]. Generally, TLVs (Threshold Limit Values) are used to assess heat related stress. Because stress is a critical contributing factor to fatigue (or work performance), as the level of stress increases the productivity of workers decreases [8].

Often personal health condition (or endurance) plays a critical role in evaluating workers' performance. OSHA focuses on the prevention of accidents in construction, personal health conditions must be in the equation in order to precisely predict what a worker's physiological responses would be. To provide each worker with a proper suggestion based on personal health conditions, it is important to understand relationships between job site factors and personal physiological responses. By learning the patterns of physiological responses under normal or work environment, potential health risks can be predicted. A set of wireless/mobile sensors are used to collect physiological responses and job site constitutions.

Presently, there is few formal health surveillance and safety monitoring of workers in the construction industry. Also, intensive hazard analyses at construction sites are rarely performed. There is no law which requires owners or contractors to provide health reports of the workers. The employer rarely knows the health status of his workers and they are made to follow the same work schedule irrespective of their job, the site, weather and other such factors. But, there are high health risks (e.g. stress; fatigue; musculoskeletal disorders; etc.). Due to a lack of effective and accurate data collection methods, health monitoring devices for construction workers have not been successful implemented even though health

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surveillance and safety monitoring in the construction industry are a great concern

Health surveillance and safety monitoring are necessary to: (1) protect workers who are at an increased risk; (2) identify work-related ill health at an early stage so that steps can be taken to treat the condition and prevent further injury and (3) give early warning that protective control measures are no longer effective.

This research focuses on establishment of an integrated framework for enhancing work performance based on worker's physiological or physical responses. In order to achieve this goal, understanding physiological responses of workers under work or jobsite related environments must be concluded.

C. Understanding Vital Signs

A biosensor is a wireless device to monitor physiological signs. It measures heart rate, R-R interval, breathing rate, posture, active level, peak acceleration, speed and distance, GPS, and more. The relationships between physiological signs and heat related illnesses such as heat rash, fainting, heat exhaustion, or heat stroke or cold related illnesses and injuries including frost nip, immersion injury (trench foot), frost bite, or hypothermia are mapped.

Stress is a physiological response to physical activities and it is an indicator to measure human body to stress [9][10]. Regardless how toxic chemicals come to the body, inhalation (breathed in), ingestions (swallowing though), or absorption (contact with skin or eyes), physiological responses take precedence over physical recognition [11]. Thus, physiological responses can be used to predict physical signs of stress, anxiety, or fatigue.

III. PROPOSED FRAMEWORK

A. Technical Framework

Wearable biosensors are capable of tracking worker's physiological responses under work related circumstances [12][13][14] Sun et al. proposed an activity-aware mental stress detection module [10]. Biosensors are used for data acquisition and laptops are used to collect and analyze physiological signs.

The proposed framework was to find relationships between job site environments and physiological responses for a variety of construction works. Fig. 2 shows a brief frame work of real-time health surveillance using bio-sensors. Fig. 3 shows a brief entity relationship diagram (ERD) of the proposed framework and Table I shows common agronomical features are sued as shown in Table 1. In addition to key physiological signs, additional work or jobsite environment data which contribute worker's physiological signs are collected. Active (RFID) tags are used for identifying workers.

Devices such as 2.45GHz RFID Vibration Sensor Active Tag is used for detecting and recording item. It can detect either continuous or impulsive vibration. It is applicable to various security and alarm systems. 2.45GHz. Gain Adjustable Active RFID Reader is a device equipped with omni-directional antenna which can identify tagged items up to 110 yards around it. Microwave 2.45 GHz Motion Sensor Active Tag is used for identifying and performing motion observation of workers.

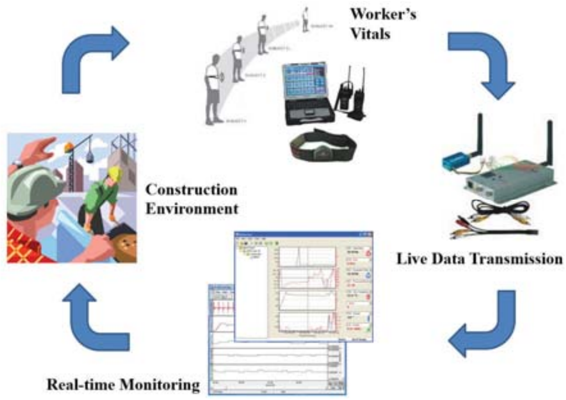

Figure 2. Framework of Real-Time Health Surveillance Using Bio-sensors [12]

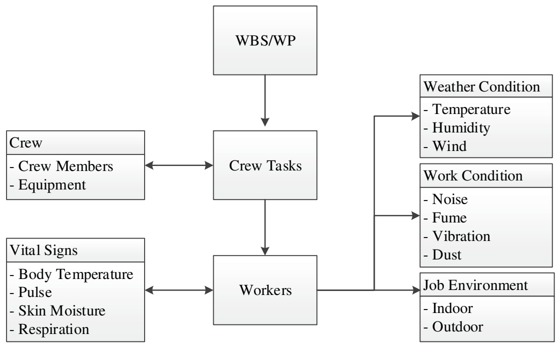

Figure 3. ERD of Real-Time Health Monitoring

TABLE 1 ADDITIONAL FACTORS AND PHYSIOLOGICAL SIGNS

Factors		
Weather-related	Work-related	Agronomical
• Air Temperature • Wind • Rain • Humidity	• Noise • Vibration • Fumes • Dust	• Overtime • Postures • Excessive loads • Repetitive motions
Stress, Anxiety, & Fatigue		

B. Integrated Monitoring Module

Construction crew scheduling and work order management are critical in order to keep the schedule as planned. A construction crew is a team of trade workers who work together closely in order to complete a construction task. Its productivity is the crew's output and an aggregate of its individual crew members. Therefore harmonizing workers at work is critical to keep its productivity. By considering labor factors affecting work productivity, task information and labor factors such as overtime are used to estimate the level of inefficiencies [15].

Not only skilled workers but also allocating equipment and materials for the work order must be completed effectively. As a work order is issued according to a contractor's construction schedule, workers' physiological responses and physical signs at work are collected and compared with those of non-work-related conditions. Using an integrated work-break schedule the project manager can complete job planning and scheduling. For example, instead of employing the standard heat index uniformly, workers can have their own set break times without affecting the work significantly. A monitoring module is used to find proper break times for involved crew members.

A few labor factors either quantitative or qualitative such as space limitation (i.e., confined space), classification of hazardous work area, working in operating areas, operating tools are considered to see if weather or work environment changes affect workers' performances.

C. Participant Questionnaire

A participant questionnaire is used to understand personal habits of participating workers. It includes physique such as age, weight, height, current medical conditions and current medications, drinking and smoking habits, type of work performing, type of equipment & tools operated regularly (mechanical, pneumatic, electric, etc.), hours of work per day, typical noise level at work, average lunch break, typical number of and duration of regular work breaks, normal begin and ending work time, normal bed time, and normal hours of sleep per night. Therefore statistical relationships between physiological responses (or vital signs) and work related factors can be learned.

IV. EXPECTED BENEFITS

This study increases our understanding and knowledge of functionalities underlying project management in construction practices utilizing advanced sensor network technologies.

Expected short term benefits include (1) dependable health surveillance. By constantly monitoring workers' vital signs, contractors can keep a medical record and health status of their crews. It can therefore, accordingly estimate crew activities and durations based on personalized health condition; (2) developing effective schedules: The model developed would equip an owner or contractor with an ideal schedule of workers involved in different trades; (3) effective crew management: contractors would be able to manage his crew more efficiently. They would exactly know the work and rest time needed for workers under job site conditions. They can effectively manage crew rotation; (4) increased worker productivity: A regular health surveillance, ideal work schedules and low risks and accidents would definitely have a great impact on workers both mentally and physically. This would lead to their increased productivity; and (5) analyze cost-benefit: This model would have both direct and indirect cost benefits. Accident and health related cost would go down. Also, a more effective work schedule would help save time, thus saving dollars. Both the contractor and owner would also save money because of increased worker productivity.

Expected long term benefits include tracking worker health records and quantifying productivity rates. Once health surveillance for workers is done for a considerable period of time, a database can be developed which would give a medical history pertinent to the job. The medical history could be linked to real time vitals of the workers to help in a better understanding of worker health; and (2) Adopting such a model over time would enable the productivity of workers to be quantified with respect to various deciding factors. Thus, scheduling can become more precise.

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