REMOTE CONSTRUCTION WORKER LOCATION, ACTIVITY AND SAFETY MONITORING

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ABSTRACT: Data fusion can be defined as a process for integrating information from multiple and heterogeneous sources to obtain a composite and augmented inference about the state of an entity. Data fusion has been successfully applied in several fields. Its usefulness is becoming evident for the enhancement of automated and remote monitoring systems of construction sites. Current technology allows the development of integrated systems able to autonomously and remotely document and track work site operations. Applications have so far focused on tracking material and equipment. Little work has been done on continuous remote monitoring of construction workers. This paper addresses the benefits and limitations of two remote sensing technologies: Physiological Status Monitors (PSMs) and Ultra Wide Band (UWB) systems, which allow real-time tracking of construction workers' location and physiological status. The scope of this paper is to evaluate the possibility of fusing data from a PSM and an UWB system to obtain an augmented knowledge of workers' status and so compensate for existing limitations. Thus, the research team is developing and testing an algorithm that is able to process the collected data to establish the position, the activity, and the safety behavior of the monitored subjects during simulated construction tasks.

***Keywords**: Data Fusion, Automated Data Collection and Analysis, Ultra-Wide Band, Physiological Status Monitors*

1. INTRODUCTION

The construction industry is usually reluctant in adopting and implementing innovative technologies. As a result, this industry is among the most conservative industries. Nevertheless, various innovative technologies provide substantial benefits as found by academics and practitioners. In particular, being able of autonomously tracking construction workers and determining their physiological conditions and activities is becoming increasingly important. In fact, it would allow great enhancements in the management of safety, productivity, and construction operations. Several existing and recently developed technologies (e.g., GPS, Ultra Wide Band, and Radio Frequency IDentification tags, Physiological Status Monitors) are available for this purpose. Unfortunately, these technologies present individual limitations that may strongly limit their successful utilization on a construction site. At the hardware level, integration among these technologies is necessary to overcome their drawbacks and to obtain an augmented real-time knowledge of workers' position and activity. In addition, the analysis of information collected from all these devices needs to cross-reference variables collected by various devices to identify descriptive and predictive models.

In this study, we propose a data fusion approach that synchronizes two real-time data streams generated by: (1) an Ultra Wide Band (UWB) system for location tracking and (2) a Physiological Status Monitor (PSM) for activity monitoring. The aim of this integration is to autonomously infer construction workers' location, activity, and safety behavior. The research team developed three simulated construction tasks where both technologies were used to collect preliminary data to proof the data fusion process. In the following, an overview about the measurement devices

is given, the simulated construction tasks are presented, and the achieved results discussed.

2. METHODOLOGY

Given the involvement of human subjects, this study was reviewed and approved by the University of Washington's Institutional Review Board.

2.1 Instrumentation

PSMs are innovative devices that can be described as non-invasive ambulatory wireless telemetry systems. PSMs can autonomously and remotely monitor workers' physiological status without hindering their routine activities for several hours with no interruptions. The research team has selected an off-shelf PSM for the experiments. Among various parameters, this PSM device is able to monitor thoracic 3D accelerations, and thoracic posture. This information is used to determine the subjects' activity and the safety behavior.

The UWB system is used to track the subjects and as activity index. In addition, the UWB system is used to determine the "ground truth" in term of positioning.

Last, a set of high-resolution network cameras is used to video-record the experiments. Visual analysis of the video-recording is used to establish a ground truth in term of safety behavior.

2.2 Experimental Design

Data were collected on various construction simulated activities (shown in Figure 1) performed by human subjects: (1) building a wall: one subject builds a wall using 23-lb concrete blocks; (2) assembling a raised deck: one subject assembles a deck using plastic supports and 16-lb concrete tiles; and, (3) assembling and disassembling a raised deck: one subject disassembles a deck and store material, another subject uses this material to assemble a raised deck in a different work area. Assembling and disassembling are dependent activities.

2.3 Data Fusion and Algorithm Development

The research team "fused" data from the three data collection systems (i.e., UWB, PSM, and network cameras). The research team is developing algorithms necessary to automatically analyze data from the UWB and PSM systems to determine a subject's safety behavior and activity. The combined data set will be used to determine the monitored subjects': (1) position, using the UWB system's data; (2) activity (e.g., placing a block, removing a paver), using the UWB system, the 3D accelerations, and body posture data; and, (3) safety behavior (i.e., following or not following the prescribed material handling technique), using the UWB system and body posture data.

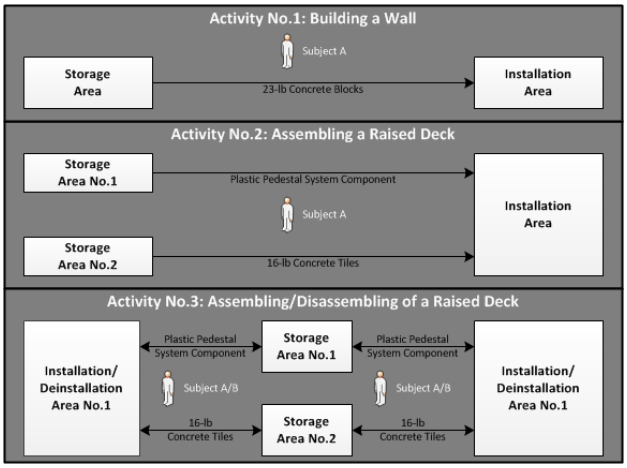

Figure 1: Construction Simulated Tasks

2.4 Algorithm Validation

The research team has developed and validated a protocol to classify the type of activity and the safety behavior, and to locate the activities on a time line. Then, the video recordings were analyzed applying the protocol to obtain a ground truth to test the accuracy of the proposed algorithms.

3. PRELIMINARY FINDINGS

The preliminary results demonstrate the reliability of the selected technologies in autonomously and remotely monitoring subjects during simulated construction activities and show promise that they can be successfully implemented to augment real-time knowledge of construction workers' status. Nevertheless, the selected monitoring technologies show limitations that have to be addressed to fully validate the proposed algorithm. For example, the research team has observed that PSM instruments sometimes shift in time the data recorded. This time shift increases with time not allowing a correct synchronization between the two data streams.