LiftingDoneRight: A Privacy-Aware Human Motion Tracking System for Healthcare Professionals

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ABSTRACT

This article describes the design and implementation of LiftingDoneRight, a novel system for healthcare professionals to enhance their compliance with best practices and regulations regarding proper body mechanics for lifting and pulling activities. The system uses Microsoft Kinect to track the motion of consented users non-intrusively. The system relies on the use of a smartwatch to deliver an alert via vibration and text display whenever a wrong activity that violated the proper body mechanics has been detected. A core contribution of this study is a registration mechanism for a healthcare professional to explicitly give permission to the system to monitor his or her activities. Furthermore, a non-intrusive biometrics-based single sign-on mechanism is incorporated into the system to allow a user to be automatically identified for tracking as long as the user has manually registered with the system before. Finally, the system offers a number of configurations to accommodate different usability needs and privacy requirements.

KEYWORDS

Alerts, Biometrics, Finite State Machine, Human Motion Tracking, Microsoft Kinect, Patient Privacy, Single Sign-On

INTRODUCTION

Lower back pains are pervasive in workplaces that involve constant lifting and pulling activities, such as healthcare, manufacturing, construction, and mining (Gropelli & Corle, 2011; Marras et al., 1993; Videman & Battié, 1999). It is estimated that the total cost of lower back injuries (including lost productivity and workers’ compensations) in the United States alone exceeds a hundred billion...
dollars a year (Katz, 2006). While the causes for lower back injuries are complicated (Burton, 1997), it has been shown that the risk of lower back injuries can be drastically reduced if a worker could follow good biomechanics in lifting and pulling, such as no bending while lifting (Marras et al., 1993). While proper training and retraining regarding good body mechanics would help, they have limited effects because they cannot be done too frequently (typically once or twice a year) for practical reasons. Training a person to have a good habit is difficult, altering the bad habit of a person is even more difficult. That is why lower back pains are still pervasive among workforces despite that best practices have been known for more than 20 years (Marras et al., 1993).

The popularity of fitness trackers and smart watches brought hope to change this situation. These wearable devices motivate people to be more active in their daily lives. It also proves that people are acceptable to wear a single tracker on the wrist. Unfortunately, proper body mechanics (or the violation of such) cannot be tracked accurately using a single sensor. Using multiple inertial sensors that are placed at proper body parts could potentially satisfy the tracking requirement. However, this approach could be quite intrusive and might even interfere with the job a worker would be doing. Hence, we conclude that other motion tracking modality is needed. Computer vision based human motion tracking seems to be a more practical option.

In this article, we present the design and implementation of such a computer vision based system, which we call LiftingDoneRight. The system uses Microsoft Kinect to track the motion of each worker non-intrusively, and can be deployed at many in-door workplaces. Tracking alone is inadequate if we hope to alter a user’s behavior. Our system relies on the use of a smartwatch to deliver an alert with proper text display as a form of intervention whenever a wrong activity that violated proper body mechanics has been detected.

We are particularly interested in deploying the LiftingDoneRight system in healthcare venues, such as nursing homes, where the activities of nursing aids are monitored by our system. In healthcare venues, federal regulations dictate that our system must respect the patient privacy. Hence, we must ensure that our system tracks only the consented healthcare professional, but not any patient. This requires our system to be equipped with a privacy-aware tracking mechanism, which a major research challenge in this study.

Computer-vision based human activity tracking has undergone intensive research for the past several decades. As exemplified by Microsoft Kinect, inexpensive computer-vision-based motion sensors can now be used to accurately track human activities in many application domains (Lun & Zhao 2015), particularly in the healthcare area, such as rehabilitation exercise monitoring (Zhao et al., 2014a; Zhao et al., 2014b) and fall detection (Mastorakis & Makris, 2014). However, such vision-based technology is rarely used in healthcare venues such as hospitals and nursing homes, primarily due to privacy concerns. The fundamental issue with vision-based motion sensing technologies is that they cannot guarantee that only the consented user is tracked due to the non-discriminative nature of the vision technology itself: anyone in the view of a vision-based motion sensor could automatically be tracked and/or recorded.

In the LiftingDoneRight system, a registration mechanism is incorporated to ensure privacy-aware selective tracking of a consented user. This mechanism is based on the integration two modalities:

- A wearable device (e.g., a smartwatch) worn by the consented user. Our system requires a consented user to wear a smartwatch, predominately to receive alerts. But the smartwatch is also needed for registration with the LiftingDoneRight system. To register, the user first presses the select button of the smartwatch, then makes the predefined registration gesture;
- Computer vision based motion sensor such as the Microsoft Kinect sensor. The designated registration gesture is confirmed by the sensor if it is observed within a predefined time period.

Even though the registration mechanism ensures privacy-aware selective tracking of consented users, having a user to repeatedly doing manual registration may be cumbersome if he/she moves
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