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MULTIMODAL SENSING FOR USER INTENTION PREDICTION IN UPPER LIMB EXOSKELETONS

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ABSTRACT

Upper limb exoskeletons promise to decrease negative physical outcomes for individuals in the workspace. Utilizing a human centric design to upper limb exoskeleton technology can remarkably improve the compatibility and user adaptation of the exoskeleton which positively affect the work performance. In this paper we present artificial intelligence based multimodal sensing modality to active upper limb exoskeletons to predict motion of exoskeleton user. Our approach involves the integration of electromyography, motion, and ultrasound sensors to detect and analyze the precise movements associated with specific work tasks. Our data analysis revealed distinct patterns corresponding to each task, suggesting the promising utility of these patterns for neural network-based user intention detection.

Keywords: artificial intelligence, exoskeleton, sensors, user intention

1. INTRODUCTION

In the workforce, many occupations still entail repetitive handling of heavy loads or working in non-ergonomic positions, such as bending over or performing tasks overhead. According to the Flemish Association of Ergonomics in Belgium, 57% of individuals report work-related physical health issues, with 46% experiencing back pain and 44% suffering from shoulder pain, all of which significantly impairs their quality of life. The emergence of upper limb exoskeleton technology offers promising prospects for mitigating these physical challenges faced by workers. The absence of commercially available active upper limb exoskeletons underscores the limitations in adaptability to users' needs seen in existing models. Consequently, there is a pressing demand for an exoskeleton controller design capable of intuitively understanding user intentions and providing task-specific assistance [1]. Numerous studies have delved into predicting user intentions using traditional machine learning approaches based on electromyography (EMG) and motion data. However, these sensors are not without drawbacks. EMG sensors are susceptible to noise and environmental factors like temperature and humidity, while motion sensors require calibration due to sensor drift [2]. Conversely, ultrasound technology shows promise in directly capturing insights into muscular motion which can provide useful information to predict the user intention [3]. In this paper, we propose a novel approach that combines various sensor modalities to predict exoskeleton user intention with neural network.

2. METHODS

Three distinct tasks have been designated for this study: the "Shelf Loading" task, the "Overhead" task, and the "Palletizing" task. In the " Shelf Loading" task, the participant is required to lift a 3-kilogram weight and place it onto shelves at three different height levels. This task is repeated 10 times. The "Overhead" task involves screwing in 5 bolts positioned above the participant's head. During the "Palletizing" task, the participant must stack 6-kilogram boxes on top of each other, repeating this action 10 times. To monitor the participant's movements and muscle activity, Xsense motion sensors are placed on various body parts, including the head, trunk, shoulders, arms, and elbows. In addition, two 64-channel high-density

EMG sensors are affixed to the biceps and triceps muscles, while an ultrasound sensor is attached to the biceps muscle. Data from motion, high density EMG, and ultrasound sensors are collected in a synchronized manner throughout the experiment.

3. DATA PROCESSING AND ANALYSIS

The collected data underwent essential post-processing procedures. First, the EMG sensor data was carefully filtered to optimize its reliability and accuracy. Subsequently, motion data was computed to derive critical information regarding joint angles and velocities, aiding in the comprehensive understanding of the subjects' movements. Dynamic torque values were calculated for each individual task. Moreover, ultrasound images were subjected to in-depth analysis, enabling the computation of crucial parameters such as velocity, pennation angle, and muscle thickness, offering valuable insights into the muscular dynamics during the tasks.

4. MULTIMODAL SENSING FOR MOTION PREDICTION

Our experimental data analysis uncovered distinct patterns connected to each activity. A clear understanding of the user's task was made possible by the obvious trends that could be seen in both the raw motion data and the derived kinematic data.

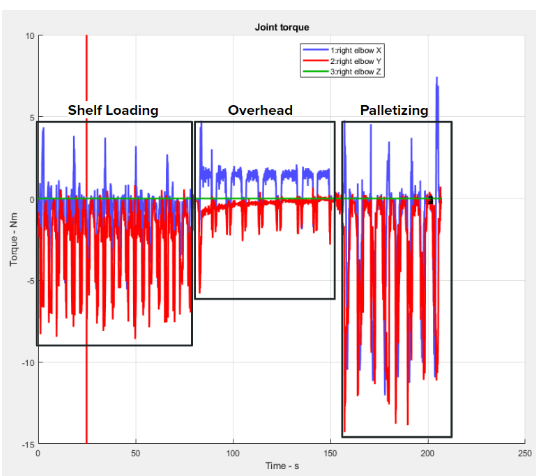

Figure 1: Calculated joint torques.

Ultrasound scans also showed noticeable differences across repeats of each activity, in addition to time series data.

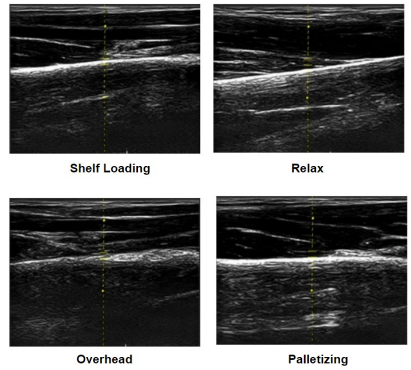

Figure 2: Ultrasound images for corresponding tasks.

The combination of these distinct sensor data patterns holds a lot of promise to be useful features for a neural network-based framework for intention prediction. These patterns can allow for accurate prediction of user movements, enabling the design of exoskeleton assistance that precisely aligns with task demands and user intentions.

5. CONCLUSION

In this work, we described a multimodal sensing approach to bring intention detection feature to upper limb exoskeleton technology. By integrating electromyography, motion, and ultrasound sensors, we were able to identify distinct patterns associated with specific work tasks, suggesting a promising feature for neural network-based user intention detection framework.

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