SLEEP POSTURE CLASSIFICATION: FROM IN-SILICO PROOF-OF-CONCEPT TO VALIDATION WITH WEARABLE SENSORS

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FIGURE 1. The set of twelve sleep postures.

MOTIVATION

Traditionally, sleep had been considered a natural mechanism to recover from exhaustion of daily activities, but recent studies showed contradictory observations. In fact, certain sleep behaviours can bring about health complications (Paquay et al., 2008), or uncover underlying disorders (Ibáñez, Silva, and Cauli, 2018). Interestingly, some studies linked sleep-related musculoskeletal morbidities to postural cues, for example, muscle cramps and painful spasms are found correlated with sustained abnormal body postures (Parisi et al., 2003). Another evidence shows that prolonged joint immobilisation could lead to muscular contractions (Akeson et al., 1987) with chronic pain episodes.

SCOPE AND OBJECTIVES

The ultimate research goal is to develop a sleep posture monitoring technology (hardware and software) to enable clinicians further study posture-triggered neuromuscular disorders. The research objectives are:

- A wearable inertial sensing solution to offer low intrusiveness, guaranteed privacy and occlusion-free posture capture.
- The classification of a large set of postures common in sleep.
- A seamless posture capture with no complex calibration or setup.
- Human interpretable posture inference results to aid clinicians in clinical studies and diagnosis.

METHODOLOGY

A sleep posture learning framework is proposed for the classification of twelve postures (depicted in Fig. 1) based on joint angle measurements at the wrists and ankles. Only one measurement per posture is required for classifier training which is later augmented with synthetic data, using a novel kinematic data augmentation method, to offer plug-and-play posture classification.

The framework was validated in two experimental pipelines:

- Virtual 3D character model animation to obtain synthetic postural dataset.
- Human participant pilot study using custom-made miniature wearable sensors (illustrated in Fig. 2).

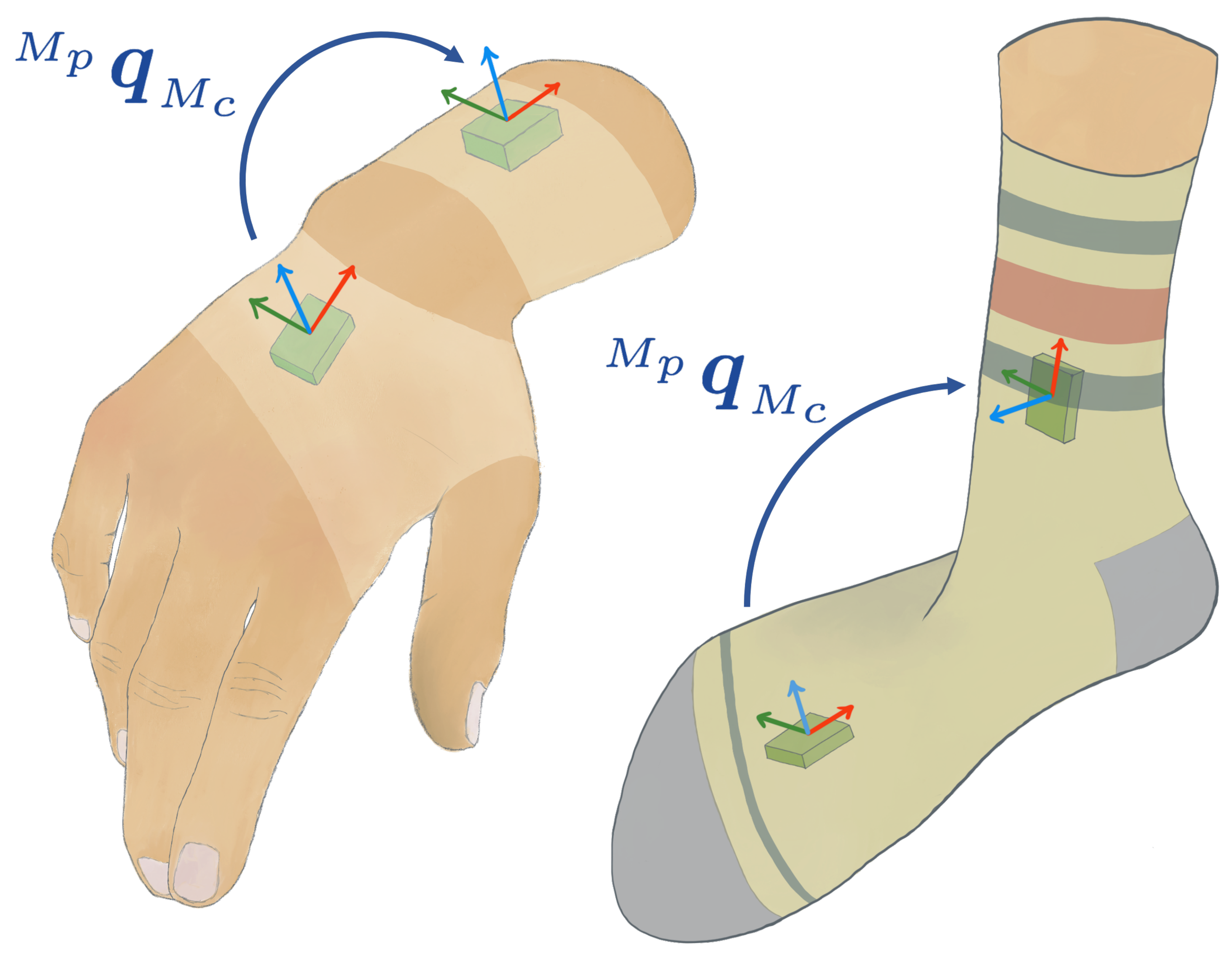

FIGURE 2. Wearable sensor placement about wrist and ankle joints for joint angle measurement.

RESULTS

The in-silico pipeline yielded an accuracy up to 100%. In-vivo experiments showed a surge in the accuracy before and after postural data augmentation.

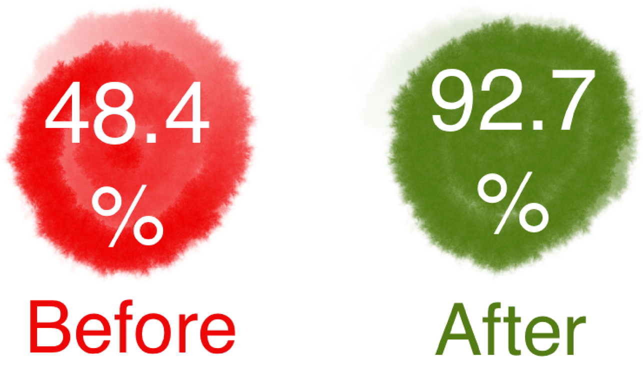

FIGURE 3. Classification accuracy before and after postural data augmentation.

Additionally, a new metric together with data visualisations are employed to extract meaningful insights from the postures dataset (refer to Fig. 4), demonstrate the added value of the data augmentation method, and explain the classification performance.

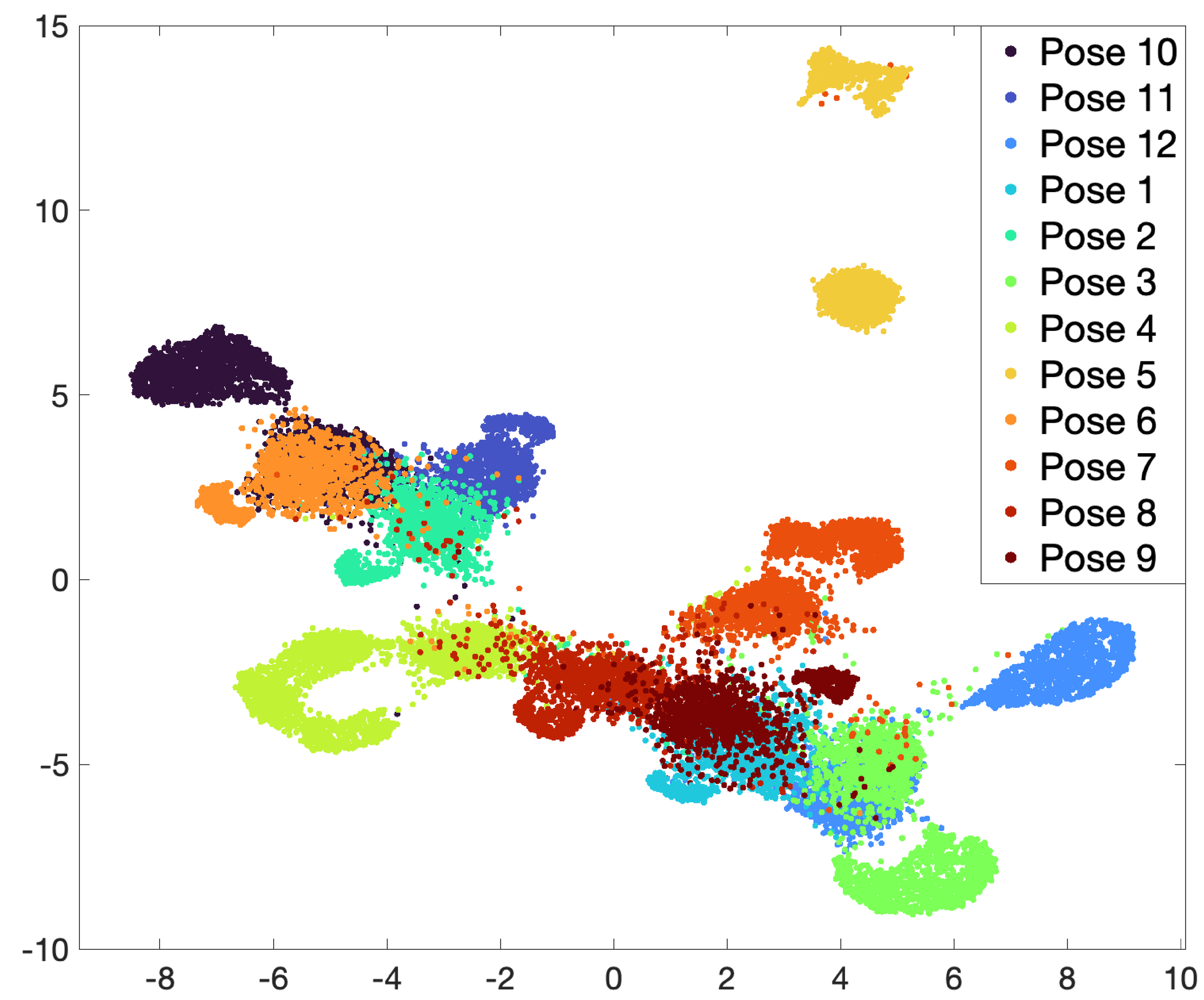

FIGURE 4. Three-dimensional (3D) visualisation of sleep posture measurements (after data augmentation).

CONCLUSIONS

A plug-and-play wearable-based sleep posture monitoring and classification system is presented. An intuitive joint angle-based posture characterisation is adopted. Supplementary metrics and visualisations were proposed to explain the overall performance and extract useful insights.

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