UNIVERSITY of WASHINGTON

DXARTS

IMU-Based Human Movement Recognition Using MINIROCKET and Application in Dance Performance

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BACKGROUND

Movement recognition technology offers new possibilities for enhancing dance practice, education, and accessibility by enabling real-time feedback, analysis, and documentation. Wearable Inertial Measurement Unit (IMU) sensors provide an affordable, portable alternative to camera-based systems, capturing motion data directly from the body. This multichannel time series data can be analyzed to recognize and differentiate movement. To classify these signals efficiently, we apply Minimally Random Convolutional Kernel Transform (MINIROCKET)—a fast, lightweight, and accurate time-series classification method. Our goal is to develop a low-cost, real-time movement recognition tool that is adaptable to the demands of live performance and creative practice.

METHODS

We collect IMU time series from patterned dance movements. The data is downsampled, smoothed, segmented, normalized, and augmented. MINIROCKET extracts features, and a linear classifier is trained to recognize movement patterns for real-time use.

Preprocessing IMU Sensor Data from Repetitive Movement Sequences

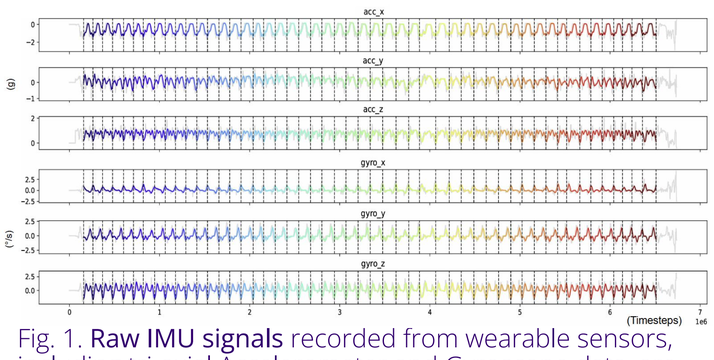

Fig. 1. **Raw IMU signals** recorded from wearable sensors, including tri-axial Accelerometer and Gyroscope data, are shown in grey. Signals are smoothed and segmented into **50 repetitions** of a triangular movement, color-coded by segment. **A total of 1350 movement segments** across multiple dance patterns (circular, triangular, linear, and random) were collected and preprocessed.

Data Augmentation Enhances IMU Signal Diversity

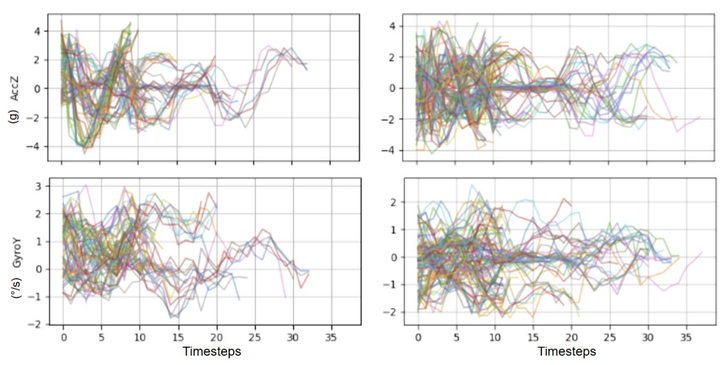

Fig. 2. Plots of 50 overlaid **original (left) vs. augmented (right) segments** of IMU time series data from all dance patterns, showing two representative channels (Acc Z and Gyro Y). After augmentation, the **dataset size increases by a factor of 6** using jittering, magnitude warping, vertical flipping, and their combinations. These augmentations introduce controlled variability while preserving movement dynamics, resulting in physically plausible and diverse signals that **enhance model generalization**.

Pipeline

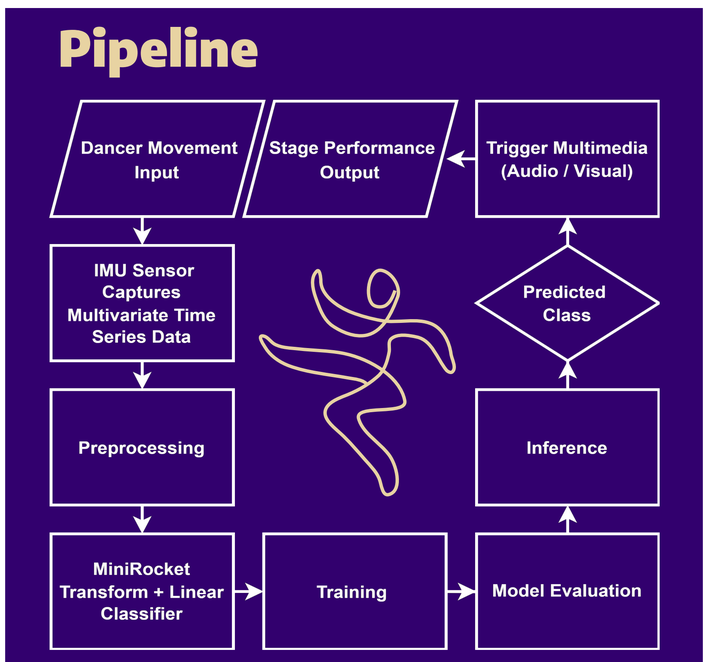

Fig. 3. **Pipeline** of the system for real-time movement recognition and application developed in this study.

RESULTS

After training on preprocessed IMU data, our classifier achieves 88.9% validation accuracy with <50 ms runtime, enabling real-time prediction of movement class to control multimedia output and complete the dancer–stage feedback loop.

MINIROCKET Classifier Training and Validation Curves

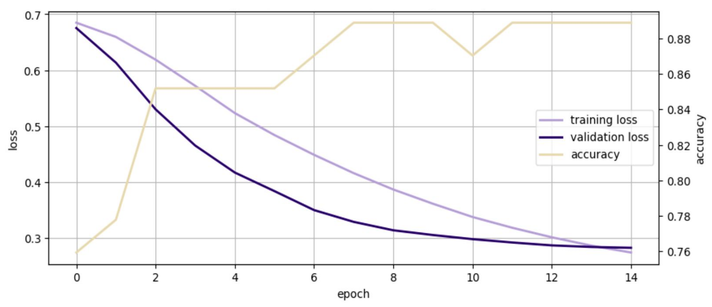

Fig. 4. **Training MiniRocket-based classifier on IMU data.** The dataset consists of 269 labeled samples, with an 80/20 split for training and validation. The model is trained for 15 epochs using a batch size of 32 and a learning rate of 1.32×10^{-4}. Training loss converges to 0.274, and validation loss to 0.283. The **validation accuracy improves steadily, reaching 0.889** by the final epoch. Total training time is approximately 3.51 seconds.

MiniRocket Classifier Training and Validation Curves

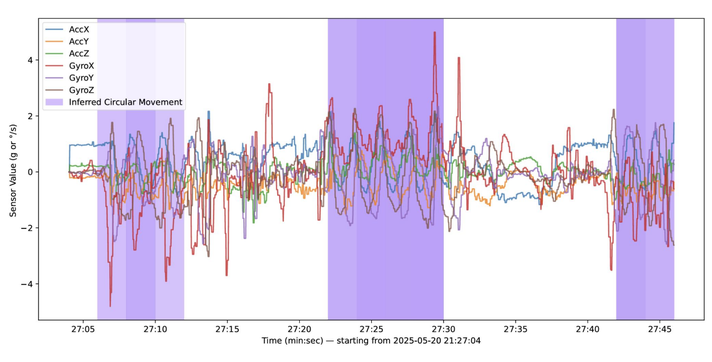

Fig. 5. **Real-time multichannel IMU movement recognition during a dance rehearsal.** Highlighted regions indicate segments inferred as circular movements by the trained MiniRocket-based classifier. The transparency of each highlight corresponds to the classifier's confidence score (ranging from 68% to 99%), **successfully aligning with the ground truth**. Each prediction window is 2 seconds long. Total runtime of the real-time pipeline is approximately 46 ms.

APPLICATION & NEXT STEP

Movement recognition expands how we document, analyze, and perform dance. From early systems like Labanotation to today's digital tools, artists have deployed many ways of scoring dance that preserve the originality of complex human movement. With wearable IMU sensors and real-time classification, we can now interpret choreography as data—opening new paths for feedback, accessibility, and creative experimentation.

This technology invites collaboration across disciplines, enabling responsive environments and hybrid performances. In our upcoming DXARTS fall concert, we will present a live performance integrating IMU-based recognition with real-time classification, exploring how computational systems can become active partners in movement-based expression.

Fig. 6. **Example application of body and movement recognition** in an interactive multimedia performance, *Fictions in Fugue*, presented at the DXARTS Fall Concert 2024 in collaboration with the Dance Department. **Future steps** include training the classifier on choreographed dance phrases and integrating the feedback system into live performances.

CONCLUSIONS

The system we propose demonstrates that IMU-based movement recognition, paired with the MINIROCKET classifier, offers a fast, accurate, and low-cost approach for real-time application in dance and performance. By capturing and classifying movement directly from the body, this method supports creative, educational, and interactive possibilities. Future work will explore expanding gesture vocabularies and integrating movement recognition into live, collaborative performance environments.

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