Efficient Multi-Positioned Training for Regression-Based Myoelectric Control: Exploring Transformer Models with Transfer Learning

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Introduction

- The human hand and wrist enable a wide range of daily activities through their complex joints and degrees of freedom (DOFs).
- Myoelectric prostheses use electromyography (EMG) signals to restore function after amputation, but replicating simultaneous movements remains challenging.
- Classification-based models lack smooth control, while regression-based models offer better simultaneous control but require extensive training.
- Changes in EMG signals from different limb positions can degrade model performance, necessitating varied position training.
- **Hypothesis: *Transfer learning can reduce training time by pre-training models on data from other users and fine-tuning them with specific user data.***
- Anticipated Benefits: This approach could make regression-based control across multiple limb positions more feasible for next-generation upper limb prostheses.

Participants: Ten participants (median age 23.5 years) without upper-body pathology.

Equipment: Six Delsys Trigno electrodes on the right forearm (Fig. 1A) recorded EMG signals at 2000 Hz.

EMG Data Collection: Participants performed single- and multi-DOF muscle contractions (Fig. 1B) in 3 limb positions (Fig. 1C), each lasting 4 seconds with rest periods.

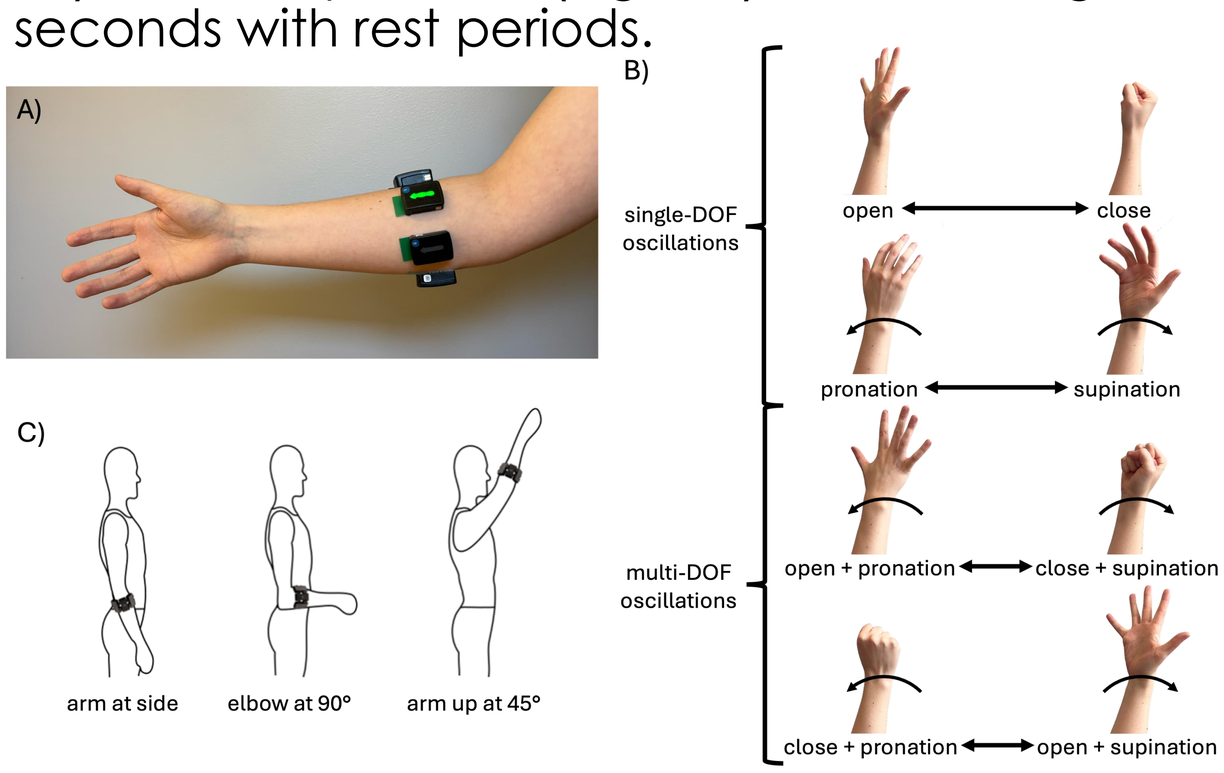


Fig. 1: A) Placement of EMG electrodes, B) single- and multi-DOF oscillating muscle contractions, and C) limb positions.

Data Pre-Processing: EMG data were filtered, segmented, transformed into spectral feature vectors, standardized, and used as inputs for the transformer, LR, and CNN regressors.

5 Regression-Based Models were developed.

- ***Standard Model (SM)*:** Trained with data from one limb position.
- ***Full Model (FM)*:** Trained with data from 3 limb positions.
- ***Few-Shot Model (FSM)*:** Trained with limited data from 3 limb positions.
- ***Pre-Trained Standard Model (PT-SM)*:** Pre-trained on data from other participants, then fine-tuned.
- ***Pre-Trained Few-Shot Model (PT-FSM)*:** Pre-trained and fine-tuned with limited data.

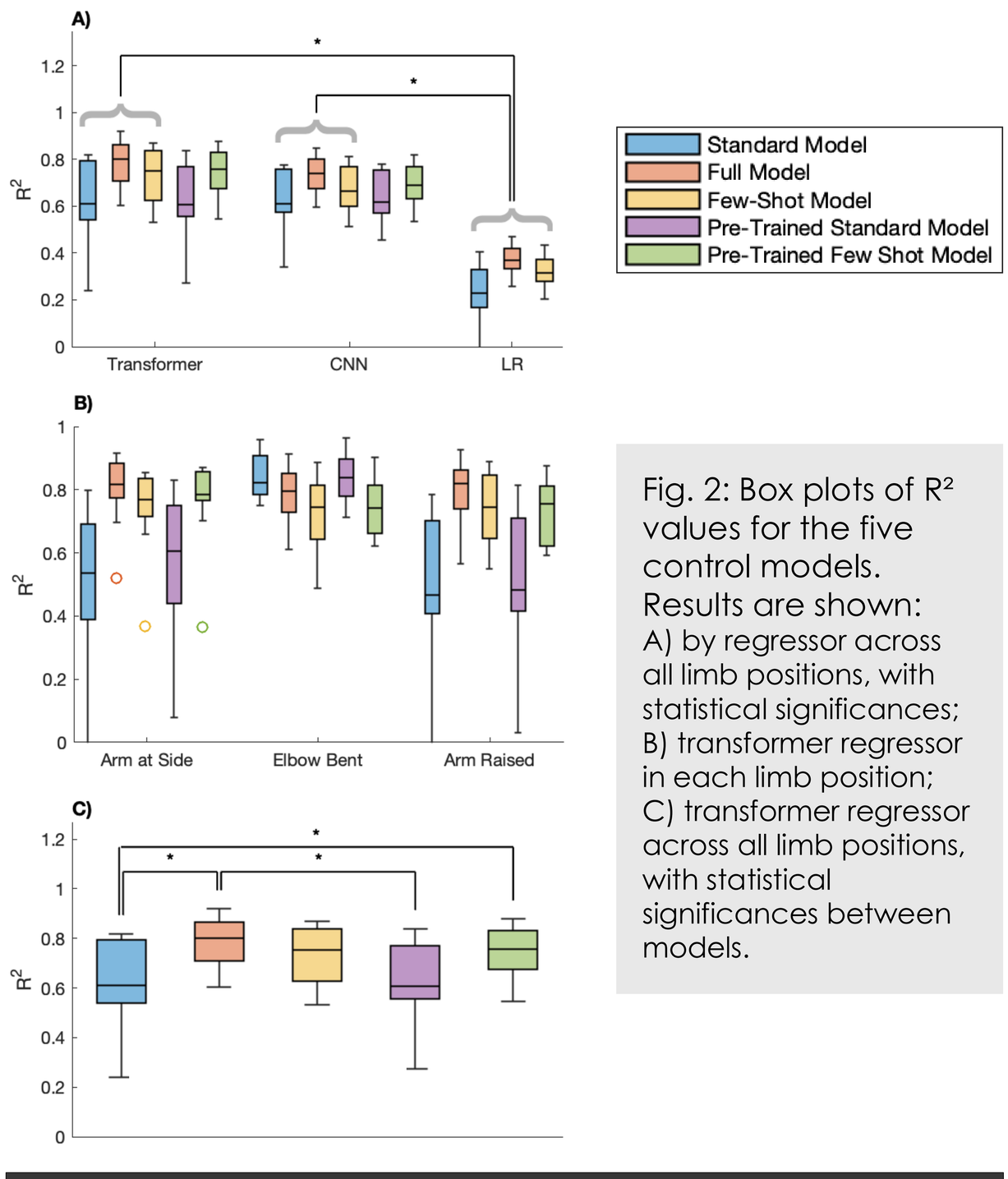


Fig. 2: Box plots of R^2 values for the five control models. Results are shown: A) by regressor across all limb positions, with statistical significances; B) transformer regressor in each limb position; C) transformer regressor across all limb positions, with statistical significances between models.

This study introduced methods to reduce training time for regression-based myoelectric prosthesis control using transformer regressors, transfer learning, and few-shot models.
Future work: real-time testing, validation with isometric contractions, a larger, more diverse participant pool, including those with limb loss.

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