

# Sim2Real Transfer and Domain Adaptation for Muscle Activation Estimation

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## Background

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Muscle activation estimation maps human motion to per-muscle activation sequences. Collecting real data with surface electromyography (sEMG) is costly and sensitive to placement, noise, and protocol choices. Simulation pipelines using musculoskeletal models (e.g., OpenSim<sup>1</sup>) therefore generate synthetic supervision; public resources, including MinT [1] make such data-driven studies feasible.

Even for real-world data such as and *emg2pose* [2], models trained in one setting often degrade in others. Shifts occur between simulated targets and real measurements, and also between real datasets due to differences in sensors, labs, subjects, and sessions. These shifts motivate a cross-domain view rather than focusing on a single dataset.

## Idea

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We study cross-domain transfer for muscle activation estimation, covering synthetic-to-real and real-to-real scenarios, with MinT used as one source among several. The aim is to design strategies that improve robustness without relying on dataset-specific fixes. There are a variety of directions to take in order to achieve this goal, leaving room for the student to propose variants and discuss them together with the supervisors:

- **Domain-invariant representations:** learn motion and muscle activation features that remain stable across capture setups and populations, so the predictor relies on information shared between domains rather than domain-specific artifacts [3, 4].
- **Distribution alignment:** match feature statistics between source and target domains so that the model encounters similarly distributed inputs at inference when target labels are scarce [4].
- **Physiology-aware calibration:** with a small amount of target data, adjust predictions to respect basic physiology. This includes *delay-aware alignment*, which

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<sup>1</sup>OpenSim project page

allows small temporal shifts to account for electromechanical delay between neural drive and sEMG envelopes, and *low-rank synergy priors*, which encourage predictions to be explained by a few shared muscle coordination patterns—reflecting how groups of muscles are commonly activated together rather than independently, thereby enforcing physiologically plausible structure across domains.

Evaluation will compare training on synthetic sources, on single real datasets, and on combinations of domains. The outcome is a set of generally applicable procedures for cross-domain transfer in this task family.

## Requirements

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This project suits students with interest in machine learning and computer vision. Proficiency in Python/PyTorch is required; familiarity with time-series modeling, OpenSim-based pipelines, and sEMG preprocessing is beneficial. The work includes a focused literature review and iterative development, testing, and evaluation across multiple domains.

## References

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