CAUSAL SEMG DISENTANGLEMENT FOR MULTI-POSTURE GENERALIZATION

Author's: A. Immaculate Vinolia[1], R. Surendiran[2], K. Sujith[3], N. Vanjulavalli[4]

Abstract

Surface electromyography (sEMG) has become a fundamental modality for gesture recognition, prosthetic control, rehabilitation monitoring, and human–computer interaction. However, practical deployment of sEMG-based systems remains challenging due to strong domain shifts caused by posture variation, electrode displacement, and inter-subject physiological differences. Conventional deep learning models often entangle gesture-relevant muscle activation patterns with posture-specific and subject-dependent nuisance factors, resulting in significant performance degradation when tested on unseen postures. To address this limitation, this study proposes a Causal Learning-Based sEMG Disentanglement Framework for Multi-Posture Domain Generalization.The proposed framework models the sEMG signal generation process from a causal perspective, explicitly separating invariant gesture-related factors from domain-specific posture effects and confounding subject influences. A shared encoder extracts latent representations that are decomposed into two components: an invariant latent space capturing gesture semantics and a domain-specific latent space encoding posture-related variations. To promote true invariance, the model integrates three complementary learning principles: (1) domain-adversarial training using a Gradient Reversal Layer (GRL) to suppress posture information in the invariant representation, (2) an Invariant Risk Minimization (IRM)-based penalty to encourage stable gesture prediction across multiple posture environments, and (3) an orthogonality regularization constraint to reduce correlation between invariant and domain-specific embeddings.