RMST: Continuous Myoelectric-to-Kinematic Decoding via Recursive Multimodal Cross-Attention and 2:4 Structured Sparsity for Bionic Prosthetic Control

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Upper-limb prosthetic abandonment remains at 44%, a clinical failure rooted in the intractable complexity of human motor control: the approximately 20 degrees-of-freedom (DoF) of the hand creates an infinite kinematic solution space (Bernstein's Paradox). Current myoelectric systems bypass this redundancy by reducing control to the classification of 6–8 static grasps—a computational shortcut that addresses the symptom, not the cause, resulting in staccato, non-intuitive movement. Inspired by AlphaFold's transformative solution to protein folding—not by brute-forcing physics, but by learning deep structural synergies—I hypothesized that a similar AI-driven approach could resolve the DoF problem in prosthetic control. Hence, my RMST architecture leverages recursive, transformer-based hierarchical modeling to map surface EMG directly to continuous, high-dimensional joint trajectories, learning motor synergies that mirror biological coordination. 2:4 structured sparsity reduced model footprint by 19.35% while preserving real-time inference of 8.97 ms (~91% below the 100 ms clinical threshold). Curriculum learning overcame temporal collapse, stabilizing convergence and resolving gradient vanishing. While regression baselines appeared competitive due to non-functional mode collapse, the RMST robustly decoded dynamic intent, yielding significant correlation gains for unseen subjects (p=0.002) and novel movements (p=0.0065). Validation in the MuJoCo engine confirmed 79.4% kinematic feasibility, linking theoretical advances to real-world movement. By directly confronting Bernstein's redundancy, this research delivers a paradigm-shifting approach: reclaiming continuous, adaptive agency for bionic users, and charting a path toward prosthetic systems as natural and intuitive as the human hand.

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