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Title
AtomSigNet: Autonomous Affective Reasoning via Atomic Biosignal Diffusion for High-Stakes Operational Stress and Health Monitoring

Abstract
A critical requirement for maintaining warfighter readiness is the ability to autonomously monitor psycho-physiological states (e.g., acute stress, cognitive load, arousal) in multi-domain operations. However, existing wearable architectures often fail due to black-box processing of noisy sensor data, limited labeled training samples for rare clinical events, and high computational overhead. We propose AtomSigNet, a framework that treats physiological signals as a sequence of irreducible atoms, enabling a self-correcting, logic-driven approach to affective state recognition. Technically, it utilizes Markovian test-time scaling to minimize latency on edge devices while leveraging generative diffusion to bridge sensor data gaps, ensuring robust, low-power longitudinal monitoring in austere environments.AtomSigNet utilizes a Markovian Reasoning Engine to model transitions between physiological states (ECG, PPG, EDA). The system identifies logic gaps, defined as the statistical contradictions where multimodal signals diverge due to artifacts, and triggers a conditional diffusion process. This process synthesizes bridge atoms to restore logical continuity in the signal chain. Importantly, the system distinguishes rare but high-integrity physiological signatures from noise, flagging them as genuine novelties for model adaptation. The framework was evaluated using the large-scale WESAD and CASE datasets, focusing on accuracy in highly unbalanced environments typical of real-world monitoring.AtomSigNet achieved a state-of-the-art accuracy of 91.6% in classifying affective states, significantly outperforming traditional supervised and self-supervised baselines. Most importantly for military applications, the framework maintained this performance with 1–2 orders of magnitude fewer labeled samples, addressing the data scarcity problem in medical research. Furthermore, the integration of Markovian test-time scaling allowed the model to dynamically expand its reasoning depth only when encountering complex physiological events. This resulted in a high-fidelity recognition system with a low memory footprint suitable for edge deployment on wearable devices.AtomSigNet provides a computationally efficient, scalable, and robust solution for continuous personnel monitoring. By grounding AI in physiological continuity and logical reasoning, this framework ensures that affective state recognition is reliable in noisy, high-stress operational environments.