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Dual-Decoder Convolutional Autoencoder for Unsupervised Anomaly Detection and Denoising in BPM Data

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Turn-by-turn beam position monitor (BPM) data are vital for fast optics diagnostics in modern colliders, but they are often degraded by noise, spikes, and signal dropouts. We present ongoing work on a dual-decoder convolutional autoencoder that addresses these issues in an unsupervised setting. A shared encoder compresses BPM waveforms into a latent representation. Two decoders then serve distinct roles. The anomaly decoder, trained on nominal data, provides reconstruction-based scores for automatic fault detection. The denoiser decoder, trained with injected faults, reconstructs clean signals for spectral analysis. Early results on SuperKEKB BPM traces show that the denoiser enhances harmonic peaks and improves tune extraction, while the anomaly branch identifies faulty channels without labels. We outline training strategies that combine simulated and experimental data, describe evaluation metrics, and discuss prospects for integration into optics workflows.

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