Implementation of Ensemble Learning Methods in Autoencoder Architecture for Anomaly Detection in Natural Gas Pipeline Operational Data

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Abstract
Pipeline monitoring plays crucial role in ensuring safety and efficiency of natural gas transportation systems. Undetected anomalies may result in severe environmental and financial consequences, emphasizing need for robust monitoring systems. Research implements an ensemble of autoencoders (EoAE) approach for detecting anomalies in natural gas pipeline operational data through integration of three complementary autoencoder architectures. These include the standard autoencoder (AE) for baseline pattern recognition, the sparse autoencoder (SAE) for selective feature extraction, and the denoising autoencoder (DAE) for noise-resistant analysis. Implementation uses unlabeled dataset spanning two years containing 61,313 hourly records with 17 features categorized into operational parameters and gas composition parameters. Averaging mechanism combines reconstruction errors from three autoencoders, establishing balanced threshold for anomaly detection. Results demonstrate ensemble of autoencoders (EoAE) successfully identified 41 anomalies (0.338\% of test data) with mean squared error of 0.581, showing improved reliability compared to individual models which detected between 39-143 anomalies at varying thresholds. Analysis reveals anomaly propagation patterns across multiple operational and compositional parameters, demonstrating system capability to identify complex behavioral changes in pipeline operations. Experimental results validate effectiveness of ensemble approach in achieving balanced anomaly detection through complementary model integration. Research advances pipeline monitoring methodology through integration of complementary autoencoder strengths for robust anomaly detection.

Keywords: Anomaly, Anomaly Detection, Autoencoder, Ensemble Learning, Natural Gas, Pipeline