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Automated Noise Source Identification in Steel Plants Using Deep Learning

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Steelmaking facilities are significant sources of environmental noise pollution, with complex acoustic emissions arising from diverse operations including Electric Arc Furnace (EAF) melting, hot rolling, scrap handling, and material transport. Effectively managing and reducing industrial noise emissions requires identifying which specific processes and equipment mostly contribute to elevated noise levels affecting surrounding communities. However, continuous monitoring systems deployed in modern steel plants generate vast quantities of acoustic data that make manual analysis and classification impractical, creating an urgent need for automated solutions.

This study presents an intelligent noise monitoring system developed within the project entitled: "Real-time acoustic sensorS and artificial Intelligence appLications for the rEduction of local eNvironmental impaCt due to noise Emissions"(SILENCE) co-funded by Research Fund for Coal and Steel (RFCS). The system is designed to automatically identify and categorize noise sources in operational steel plants without requiring manual labeling of acoustic events. The system utilizes strategically positioned microphones across critical production zones including the hot rolling mill, EAF area, coiling stations, scrapyard, and transport routes to continuously capture acoustic emissions triggered when sound levels exceed predefined thresholds.

The core innovation lies in applying advanced unsupervised machine learning techniques to automatically group similar acoustic events and identify their operational sources. The approach combines Variational Autoencoders with Gaussian Mixture Models to learn characteristic acoustic signatures directly from recorded sound data, represented as Mel-spectrograms that capture frequency and temporal patterns. This methodology enables the system to discover natural groupings in complex, overlapping industrial soundscapes without prior knowledge of event categories.

Comprehensive evaluation demonstrates that this deep learning framework significantly outperforms conventional clustering methods. The system achieves superior separation and identification of distinct acoustic events, with quantitative metrics showing improvements compared to traditional approaches. Testing on both industrial steel plant recordings and benchmark urban sound datasets confirms the robustness and generalizability of the methodology.

The practical implications for steel producers are substantial. Plant operators gain automated tools to pinpoint specific processes responsible for noise complaints, enabling targeted mitigation measures. The continuous monitoring capability supports compliance with environmental regulations by providing objective documentation of noise sources and their temporal patterns. Furthermore, the system's unsupervised nature eliminates the need for extensive expert annotation, allowing rapid deployment across different facilities and operational contexts.

This work represents a significant advancement toward sustainable steelmaking operations, providing an efficient, scalable, and automated solution for industrial noise management that balances production efficiency with environmental responsibility and community relations.

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