Contribution ID: **121** Type: **Keynote Presentation**

Image-Based Steel Scrap Mixture Recognition Using Deep Neural Networks

Monday 11 May 2026 14:10 (20 minutes)

Steel scrap recognition plays a crucial role in energy consumption optimization in the electric arc furnace (EAF) steel production process. Scrap picking for basket loading is traditionally in charge of the operator, who operates based on the expected charge mix. This process is prone to human operator errors. Scrap loads typically consist of heterogeneous mixtures of metal waste with diverse shapes and sizes, often comprising multiple scrap classes within a single batch. Thus, the scrap mixture recognition can be defined as estimating the contribution of scrap classes present in the load.

In this article, we propose a data-driven method for steel scrap recognition based on convolutional neural networks. We utilized ResNet50 architecture due to its excellent performance in image recognition tasks. To adapt the model to predict mixture proportions instead of one-hot class labels, the network is modified by replacing the original classification head with a trainable output layer and applying a softmax normalization. The model is trained using Kullback-Leibler (KL) loss function that directly compares predicted and annotated scrap class distributions. The dataset consists of approximately 46000 industrial images, annotated with soft labels representing mixture proportions and spans 21 scrap classes. The classes are a customer extension of standard European steel scrap specification EU-27. Training and evaluation are conducted taking into account the class imbalance. The model predictions, then, along with EAF operators' knowledge are processed with generative ai to suggest optimal furnace parameters and highlight potential issues between scrap mixture and furnace parameters.

Model performance is primarily evaluated using distribution-based metrics aligned with soft-label formulation of the problem. In particular, macro-averaged and weighted mean absolute error (MAE) are used to quantify deviations between predicted and ground-truth mixture proportions. The trained model achieves a macro-averaged MAE of 2.04% and a weighted MAE of 3.97%, indicating that predicted mixture compositions deviate from ground truth by only a few percentage points on average. Per-class error analysis shows that higher prediction errors are mainly associated with underrepresented classes.

These results demonstrate that convolutional neural networks are a viable solution for steel scrap mixture recognition in real industrial environments. Future work will focus on expanding the dataset beyond 100000 images, improving performance for low support classes, and exploring more expressive model architectures to further enhance accuracy.

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Session Classification: Scrap management and quality improvement

Track Classification: EEC 2 - Process Optimization: EEC 2.B Optimization of raw material usage, including scrap metal and direct reduced iron (DRI)