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Improving Safety in Steelmaking Operations through Advanced Computer Vision and Machine Learning within the iSteel-Expert Project

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The iSteel-Expert project pioneers an advanced computer vision and machine learning framework for monitoring and analysis of Electric Arc Furnace (EAF) operations within steel plants. Co funded with the European Research Fund for Coal and Steel (RFCS) G.A. 101112102, the project's core mission is to develop a remote expert virtual system that enhances operator situational awareness, preserves expert knowledge, and fosters improved safety and process efficiency in 24/7 industrial environments.

This presentation focuses on the deployment and performance of several AI-powered vision modules designed to monitor critical aspects of the melting phase:

1. Human presence detection
   Leveraging deep-learning object detection architectures, the system identifies personnel presence in high-risk zones around the EAF. This ensures that operators are aware of human location relative to hazardous operations, reinforcing safety protocols and minimizing accident risk.
2. Electrode smoke detection
   A deep-learning model analyzes images to detect early signs of fumes emissions around the electrodes and roof. Building on pretrained convolutional neural networks via transfer learning, this module extracts visual cues to flag potential occurrences of dangerous reactions.
3. Slag door state detection
   By analyzing camera feeds near the slag door, the system classifies whether the door is obstructed. This capability supports automated tracking of slag-removal timing and alerts operators to abnormal or unsafe states.
4. Electrode movement speed estimation
   Applying optical flow and frame-to-frame correlation, the system determines the position of the electrode and its up-and-down velocity. Movement monitoring provides critical insights into process control and identifies potential mechanical or control system degradation.
5. Electrode-tip shape monitoring
   Leveraging convolutional neural network-based segmentation, the system models and periodically assesses the electrode's tip geometry. Detecting anomalies or wear extends electrode life, minimizes unplanned downtime, and informs maintenance planning.

These modules form part of iSteel-Expert vision system which integrates cutting-edge AI techniques to reinforce safety, optimize process efficiency, and enhances knowledge preservation in steelmaking operations.

Initial deployment within the industrial EAF environment in Pittini Siderpotenza demonstrate reliable detection performance and alerting capability, supporting improved process transparency and operator decision-making. Moreover, the results highlight the potential for broader application of computer vision in the metallurgical domain and underscore the value of multidisciplinary collaboration in Industry 4.0 transformations.

Future work will focus on large-scale validation of KPIs, refinement of AI modules, and training system assessments.

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