Image-Based Process Control: A CNN Approach for Joint Detection and Localization in Spatiotemporal Fault Analysis

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Convolutional Neural Networks (CNNs) have emerged as one of the most effective tools for image analysis. In this study, we propose a custom-designed CNN architecture to construct a process control scheme based on image data. The product image is partitioned into equal-sized grids, each comprising three channels. To train the model, we generate synthetic datasets representing both in-control and out-of-control conditions, tailored to reflect the specific nature of the monitoring task. The proposed method offers dual capabilities: it not only detects multiple simultaneous faults in different regions of the image but also localizes the positions of these faults; both in a single step. Performance evaluation is conducted using run length metrics for detection effectiveness and the Dice score for fault localization accuracy. Extensive simulation studies are carried out to assess the scheme's performance under various shift magnitudes and spatial configurations. Comparative analysis with recently developed control schemes demonstrates the superior performance of our approach in detection, localization, or both across numerous scenarios. Finally, we provide a practical case study to illustrate the implementation of the proposed method in a real practice.

Keywords: Convolutional Neural Networks, Process Control, Image analysis, Spatiotemporal, Monte Carlo Simulation