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Optimizing Machine Learning Algorithms for Defect Characterization and Elimination in Liquids Manufacturing

Authors : Tolulope Aremu

Abstract : The key process steps to produce liquid detergent products will introduce potential defects, such as formulation, mixing, filling, and packaging, which might compromise product quality, consumer safety, and operational efficiency. Real-time identification and characterization of such defects are of prime importance for maintaining high standards and reducing waste and costs. Usually, defect detection is performed by human inspection or rule-based systems, which is very time-consuming, inconsistent, and error-prone. The present study overcomes these limitations in dealing with optimization in defect characterization within the process for making liquid detergents using Machine Learning algorithms. Performance testing of various machine learning models was carried out: Support Vector Machine, Decision Trees, Random Forest, and Convolutional Neural Network on defect detection and classification of those defects like wrong viscosity, color deviations, improper filling of a bottle, packaging anomalies. These algorithms have significantly benefited from a variety of optimization techniques, including hyperparameter tuning and ensemble learning, in order to greatly improve detection accuracy while minimizing false positives. Equipped with a rich dataset of defect types and production parameters consisting of more than 100,000 samples, our study further includes information from real-time sensor data, imaging technologies, and historic production records. The results are that optimized machine learning models significantly improve defect detection compared to traditional methods. Take, for instance, the CNNs, which run at 98% and 96% accuracy in detecting packaging anomaly detection and bottle filling inconsistency, respectively, by fine-tuning the model with real-time imaging data, through which there was a reduction in false positives of about 30%. The optimized SVM model on detecting formulation defects gave 94% in viscosity variation detection and color variation. These values of performance metrics correspond to a giant leap in defect detection accuracy compared to the usual 80% level achieved up to now by rule-based systems. Moreover, this optimization with models can hasten defect characterization, allowing for detection time to be below 15 seconds from an average of 3 minutes using manual inspections with real-time processing of data. With this, the reduction in time will be combined with a 25% reduction in production downtime because of proactive defect identification, which can save millions annually in recall and rework costs. Integrating real-time machine learning-driven monitoring drives predictive maintenance and corrective measures for a 20% improvement in overall production efficiency. Therefore, the optimization of machine learning algorithms in defect characterization optimum scalability and efficiency for liquid detergent companies gives improved operational performance to higher levels of product quality. In general, this method could be conducted in several industries within the Fast moving consumer Goods industry, which would lead to an improved quality control process.

Keywords : liquid detergent manufacturing, defect detection, machine learning, support vector machines, convolutional neural networks, defect characterization, predictive maintenance, quality control, fast-moving consumer goods
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