Surface Defect Detection, Classification and Root Cause Diagnosis in Hot Rolling Process

Hongbin Jia

Doctor of Engineering in Manufacturing Oral Defense

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1515 HH Dow Building

Co-chair: Jianjun Shi, IOE
Co-chair: Yi Lu Murphey, Elec. & Comp. Sci. (Dearborn)
Committee Member: Julie Ivy, Ross School of Business
Committee Member: Tzyy-Shuh Chang, OG Technologies, Inc.

Steel hot rolling process is a complex manufacturing process. The recent development of sensing techniques makes it possible for inspecting the surface quality status of hot rolled products online. In this thesis, an intelligent machine vision system was developed to detect surface defect, classify the detected defects into different categories and analyze root causes for the hot rolling process. There are three indispensable components of the system.

Two different categories of efficient feature extraction methods based on image signals are developed for the defect detection of the hot rolling process. Local features are calculated based on image processing to find those individual non-repeating defects. Global feature extraction algorithm, which is robust against noises, is based on autocorrelation coefficients for analyzing the repeating defect patterns. The related parameter is optimized to make the feature extraction more robust for the repeating defect patterns analysis. The online application of the algorithms shows they are fast enough to be incorporated in a real-time rolling process manufacturing line and robust to the variance of lighting, surface texture, and foreign inclusion. The extracted features are used as the input to the intelligent classification system for decision-making.

A Support Vector Machine (SVM) technique based machine learning system was investigated. Two different SVM classifiers, two-class SVM and one-class SVM, are used both for the incremental learning process and prediction process. An efficient parameter selection method for training SVM classifiers is introduced based on one-class SVM. The incremental learning system based on SVM is proposed. The system can automatically detect the new defect categories by describing the current known defect categories as current knowledge domain. The system updates itself in an incremental fashion to accommodate new data without compromising classification performance on old data. *Incremental class learning* and *incremental data learning* are integrated into one learning system. The self-learning intelligent system that meets the requirement for the online application can expend its knowledge automatically.

Two different root cause diagnosis approaches for rolling defects are explored according to the availability of the background knowledge about the mechanism of defect generation. Knowledge driven diagnosis approach will be used when the physical generation mechanism of the detected defects is known. Data driven diagnosis approach will be used for the case that the physical generation mechanism of the detected defects is unknown. With efficient defect root cause diagnosis, the rolled product quality may be improved by removing the problematic manufacturing parts or changing the related process variables through process control.