ABB Surface Inspection System (SIS) utilizes the latest technologies in machine vision to produce unmatched quality images and classification of surface defects - all online and with full strip coverage.

Defect Classification with the ABB Surface Inspection System

Introduction

Online measurement of flat steel surface quality opens up vast possibilities. The most impressive benefits from a full-coverage machine vision inspection system are achieved by minimizing rejections and scrap caused by surface quality defects. Unnecessary customer complaints can also be greatly reduced by utilizing the information obtained by an inspection system. The ABB Surface Inspection System (SIS) provides a tool for consistent full-coverage inspection. Collecting and analyzing defect data assists decision-making when rejection or scrapping are considered. Maintenance and process development can also utilize the defect information collected. The system enables the tracking of changes in surface quality and the utilization of history data to further optimize the production line's capabilities.

In order to satisfy the requirements set for a fully-fledged surface inspection system, ABB has focused on the reliable and sensitive detection of all kinds of surface defects. The outstanding quality of the defect images has also been a key design principle. The high quality of the defect images ensures not only good visualization of the defects but also provides a good starting point for the powerful classification and classifier training tools. This article gives an overview of surface inspection systems and describes the ABB SIS in more detail. It also introduces a new concept for creating accurate defect classifiers.

ABB SIS OVERVIEW

The ABB Surface Inspection System constantly monitors the moving strip. When turned on and running, the ABB SIS measures and detects the deviations in reflectance intensity with 100% strip coverage. When a passing defect is detected, an SIS camera captures an image of the defect. The ABB SIS uses fast proprietary digital line-scan Smart Cameras for noise-free and reliable image acquisition. A digital line-scan camera allows measurements with optimal reflectance angles with no geometrical distortions. Different product categories have different surface reflectance factors. In the ABB SIS this is taken care of by controlling the intensity of the light source. In order to guarantee the best image quality and comparable appearance of the defect images, the ABB Smart Camera also adjusts the measured signal strength, making the defect image illumination constant through the images.

Image analysis and defect segmentation

The segmentation of the defects is separated from the detection phase, thus allowing separate algorithms and sensitivity levels to be optimized for both tasks. Segmentation and feature extraction of the defect image provide - along with all the position and process information - all the data needed by an automatic classifier.

A grayscale image is captured for each defect detected. This defect image is then further processed with specialized image analysis methods. During the analysis the actual defect areas are extracted from the varying background texture. This is done by utilizing texture-sensitive filters and many different types of area processing methods. The results of the segmentation phase are the regions of interest, ROIs.

Once the ROIs have been identified from the defect image, the classification features can be computed directly using the defect image and the ROI information. The task of classifying surface defects is challenging and needs features especially designed for the application area. Adding to the complexity of the task, each production line has its own characteristics and defects, which may have a unique appearance, not met anywhere else.

Classifying surface defects

A defect with classification features can be classified by using a pre-trained classifier or some heuristically defined rules, in the form of a decision tree, for example. The ABB SIS Smart Classifier utilizes both of these methods. A decision tree is used for feeding the classifier with *a priori* information. For example, defect classes appearing only near the edges can be ruled out of the possible classes for defects detected in the middle of the strip. It is rarely possible to classify real surface defects into dozens of classes based on a few features only. The construction of a set of expert rules for classifying all defects into multiple defect classes is a very labor-consuming task with a constant need for fine-tuning. The number of features needed grows with the number of classes and with the similarity of the classes to be separated. In order to avoid misclassifications arising from falsely adopted rules in the decision tree, only such rules that can be considered non-changing and at least nearly 100% correct for all defects in all situations are included in the decision tree. The rest are left for a trainable classifier capable of fitting into any number of class distributions and any number of features.

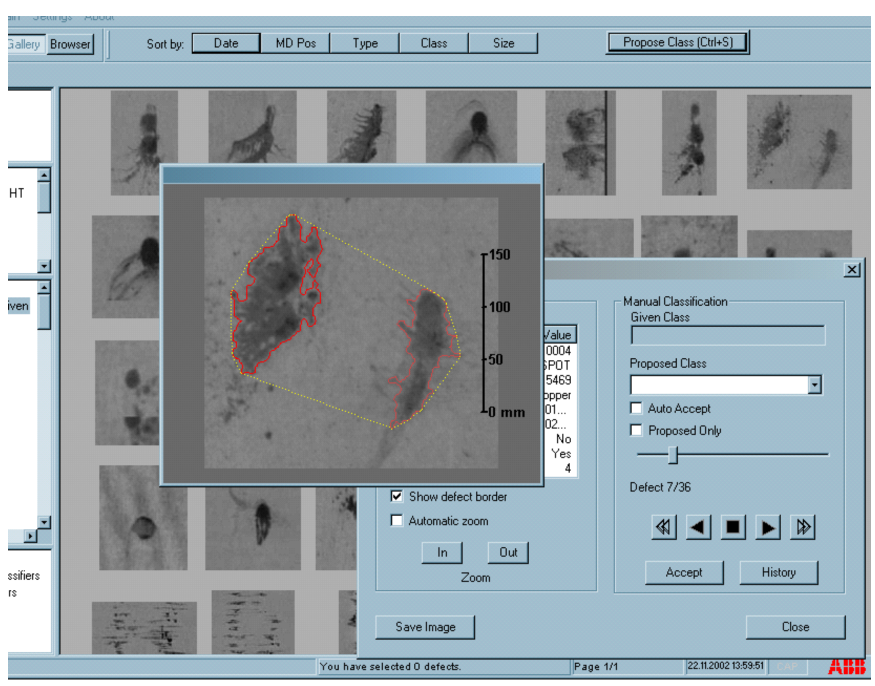

Figure 1: 'Defect Viewer' showing a detailed view of an unclassified defect image. A gallery of thumbnail-sized defect images, seen in the background, reveals many similar looking surface defects readily organized by the application.

Creating training material for the classifier

Any trainable classifier uses a reference set of manually classified samples. These samples are referred to as the training material. The quality of the results for such a classifier depends mainly on two factors: the quality of the aforementioned feature set and the quality of the training material. The more complete the training material the better the results are for new samples. The creation of the training material is a time-consuming task. In order to create an adequate amount of training data one needs to browse through thousands of defect images just to find all the different types of defects. To make this process easier and faster, ABB has developed a new concept and a new type of tool to support it. The tool provides the user with two co-operating and effective approaches for navigating the defect image database.

The first approach is a more conventional rule-based filtering of the defects. The user can select the required set of defect images from the entire image base by selecting different search criteria from an easily navigable tree structure.

The second approach for browsing the defect images is even more user-friendly and intuitive. By utilizing the self-organizing map (SOM [1]) technology, the defect images are readily clustered, i.e. organized into meaningful groups, as seen in Figure 1. For each group, a set of sample images is shown on a view pane. From the 'image map' the user can navigate to take a closer look at the defects in the selected area of interest. The user can then compare many similar looking defects, or defects from various different clusters, and at the same time give them the correct classification labels. By doing so the user efficiently creates training material for a trainable classifier.

The actual defect images can be shown on the monitor in full size, giving the user a good idea about the severity of the defect.

Having similar defects at hand greatly increases the consistency of the manual defect classification process and subsequently the classification accuracy of the trainable automatic classifier.

Training a classifier

Once a set of comprehensive training material has been created, it is time to train an automatic classifier.

The ABB SIS Smart Classifier uses neural network techniques together with the ability to utilize user-definable expert rules.

Once the classifier has been trained and activated, it is ready to classify any incoming new samples, that is, the defects detected and analyzed by the surface inspection system.

References

1. T. Kohonen, Self-organizing Maps, Springer Verlag, 2000