44 Fault Analysis of Running Paper Web

Jukka Iivarinen and Ari Visa

On-line inspection is an essential part of modern web or sheet manufacturing. There are plenty of applications in different processes, e.g., in paper, nonwoven, plastic, metal, and plywood industries. The purpose of an inspection system is to detect and classify those defects which impair the quality of a product as compared to the requirements set by a user. The requirements mostly deal with the suitability of a product for the intended use of it. Certain defect types are so harmful that their presence in a product will make its further processing or converting difficult or impossible.

Typical characteristics of web manufacturing processes, when compared with other sheet or flat product manufacturing, are the large values of web width and production speed. Paper manufacturing is an extreme example of such demanding web processes. The web width of a modern paper machine may exceed 9 metres and its speed may reach 30 m/s. Such a machine makes about $3{\cdot}10^8 \mathrm{mm}^2$ of paper each second, and all that production has to be inspected with a 100 % coverage. The inspection task is made more difficult by the fact that often the size of the smallest defects which have to be detected is smaller than a square millimeter.

Historically defect detection of web surfaces has been accomplished by hardware solutions for thresholding and matched filters. These techniques have made possible to detect only the most basic defect types. Detection of more complicated but critical defect types has remained unreliable. In this project more sophisticated methods have been developed. Use of texture and more complicated classifiers have become possible due to new sensor technology, increased calculation capability of computers and specialized hardware. Surface inspection has been studied in the Laboratory of Computer and Information Science at Helsinki University of Technology since 1995 [1-4]. The main interest has been the detection and classification of defects in a running paper web.

44.1 Overview of the Method

The proposed system model for web inspection has two phases: a segmentation phase (defect detection) and a classification phase (defect classification) (Figure 92). In the segmentation phase feature extraction is done and potential defect areas are marked. In the classification phase features describing the shape and internal structure of defects are extracted and defects are classified to different defect classes.

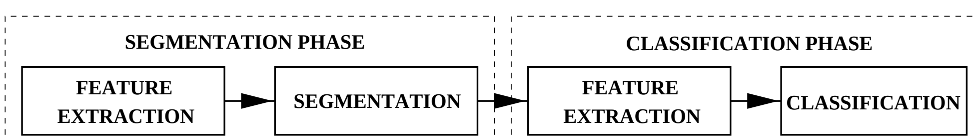

Figure 92: The proposed method consists of two phases.

The self-organizing maps (SOMs) are used in both phases. In defect detection a modified SOM, called the statistical SOM, is used to separate defects from a fault-free web. It is taught only with samples taken from a fault-free web. In defect classification the SOM is used to cluster unknown defects. It thus finds the classes (clusters) that are inherent to defect samples. These classes are then given an explanation (or a label) by hand.

44.1.1 Segmentation Phase

Images of many surfaces can be considered as stochastic textures, hence the co-occurrence matrices are used for the texture description. The co-occurrence matrix is reduced to a set of features to make calculation time and memory requirements smaller. The co-occurrence matrices are calculated locally within a small window that glides across the image.
The statistical self-organizing map is used to estimate the distribution of features extracted from faulty-free samples. Fault detection is based on the following idea: an unknown sample is classified to a defect if it differs enough from this estimated distribution. The segmentation scheme is depicted in Figure 93. An example base paper image and its segmentation is given in Figure 94.

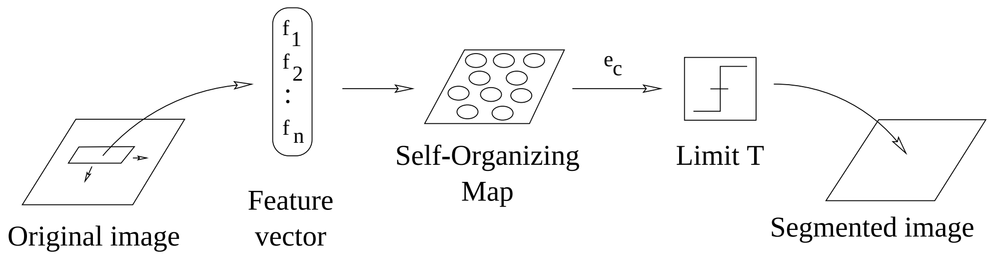

Figure 93: The segmentation scheme.

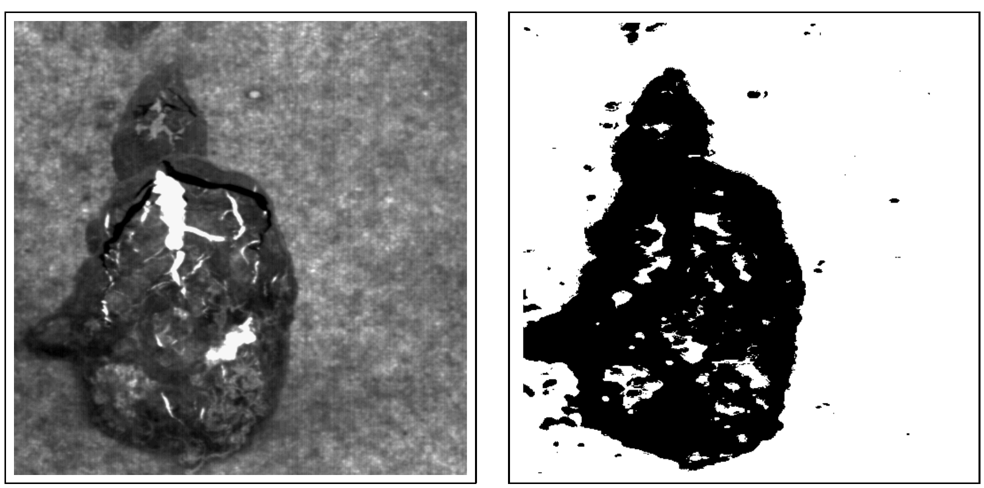

Figure 94: A base paper image and its segmentation. Defects are marked with black color.

44.1.2 Classification Phase

Due to the 2-dimensional nature of paper, most of its defects can be regarded as optical surface flaws which are detectable by a human eye. Therefore, classification is commonly based on their visual appearance, namely on their shape and internal structure. Five simple shape descriptors are used to characterize the shape, and a gray level histogram and some co-occurrence matrix features are used for the internal structure.

The proposed defect classifier is depicted in Figure 95. There are three stages: a pre-processing stage, a classification stage, and a combiner stage. The classifier stage has three branches, one branch for each feature set. Each branch has a feature extraction unit and a classification unit. The outputs from the classification stage are combined in a combiner to produce the final classification.

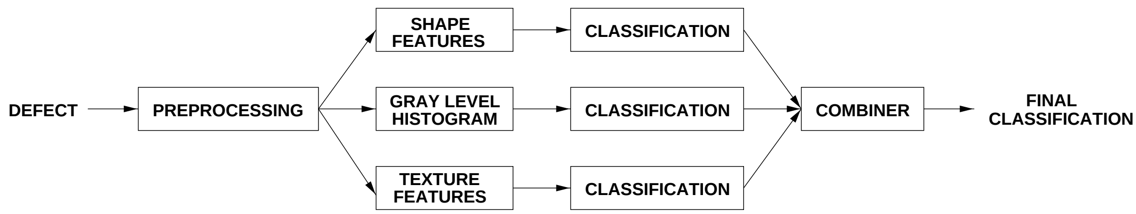

Figure 95: The defect classifier.

The codebooks are formed with the self-organizing map (SOM) algorithm. The advantage of using the SOM in codebook generation lies in the fact that the codebooks can be formed in an unsupervised way, simply by clustering unclassified training samples together, and then labeling the SOM units (or clusters) to represent different classes. In addition to manually given labels each SOM unit can be assigned a few representative defects. They act as examples of typical defects that belong to a SOM unit.

An example defect and its features are depicted in Figure 96(a). In Figure 96(b)-(d) are the classification results. Each column shows the best-matching codebook defect when using different features. In the bottom row are the numbers and the weight vectors of the best-matching SOM units. The first and the second row show one of the typical defects (with its feature vector) that belongs to the best-matching unit. The labels of the best-matching units are *elongated, smooth shape* (SSD), *light spot* (GLH), and *light spot* (TEX). The final classification is then *elongated, smooth, light spot.*

44.2 Conclusions

The two-stage approach offers advantages when considering real-time processes. Speed requirements of real-time defect detection and classification can be satisfied by splitting the needed procedure into two stages. The defect detection is a suitable part to hardware implementation. It is computing intensive. However, the adaptation is simple and concerns only the codebook vectors. More time can be spend on classifying found defects, because it can be assumed that defects are rare. The proposed two-stage classification procedure is a general one and can be used in different classification problems. Reselection of features may be necessary to adapt the proposed classifier to work with different types of surfaces and defects. In defect detection the classifier is taught with examples of fault-free surface while in defect classification shape and internal structure characteristics of defects are

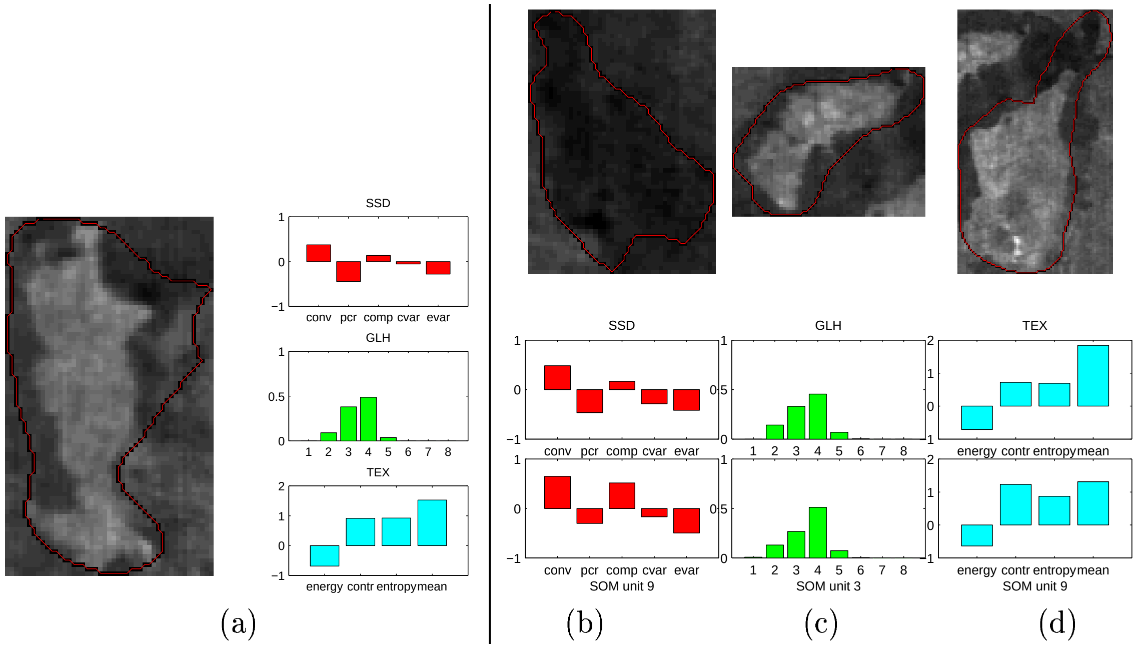

Figure 96: (a) A defect and its shape features (SSD), gray level histogram (GLH), and texture features (TEX). The best matching defects to the defect in (a) with respect to (b) the shape, (c) the gray level histogram, and (d) the texture features.

learned from examples. The self-organizing maps (SOMs) are used as classifiers. The defect classifier allows new, previously unknown, defects to be added to the codebook gradually during a long period. This is necessary since collecting samples of all possible defects is a time-consuming task and thus it is not reasonable to do it before initial training.

References

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