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An application of rough set theory to defect detection of automotive glass

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Abstract

A technique based on rough set theory is investigated for identifying defects on a backlight (a rear window of a vehicle with a defrost circuit). Since replacement of defective backlights result in a significant financial loss, automobile manufacturers are trying to remove defective backlights during the manufacturing process. Therefore, an automated inspection system based on infrared (IR) imaging techniques has been developed to detect backlight defects such as missing lines or hotspots, where the most challenging task is identifying hotspots from their artifacts.

Feature selection techniques based on rough set theory are explored in this paper and are used to extract a feature vector, which increases inspection accuracy as well as reduces computational complexity. The theory is also applied to generate decision rules, which can be simply added to existing inspection systems to assist the operators in their decision making process. The proposed inspection system is expected to provide more reliable fault detection with low rate of false alarms than currently available systems.

Keywords: Rough set theory; Automated inspection system; Feature selection; Rule generation; Automotive glass

1. Introduction

In automotive industries, a defective backlight is considered as a significant source of financial loss as well as a source for assembly delays and warranty violations. Therefore, automobile manufacturers have been trying to screen the defective part in its manufacturing stage. As a result, an automated inspection system, which analyzes an infrared (IR) image of a heated backlight, has been developed and tested successfully [2].

Even though the automated system replaces manual inspection successfully, enhancing the inspection accuracy is still required to reduce the rate of false alarms. The accuracy problem is focused on isolating a hotspot (a spot which produces more heat than its neighbors) correctly from artifacts. Although image-processing techniques may be satisfactory for hotspot detection, they generally impose a

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computational burden. Therefore, an innovative approach to deal with both aspects simultaneously is pursued in this paper.

Rough set theory, has been gaining attention due to its mathematical abilities to deal with uncertainty in data sets [4–6]. Many applications have proven its usefulness especially in removing redundancies and extracting hidden relationships among data items [3,8]. As a result, the theory has been successfully applied for feature extraction and rule generation [7,9].

In this paper, rough set theory is applied to an automotive glass inspection system. Conventional image-processing techniques [1] are also used to reduce search space before feature extraction, and the rough set approach selects a feature vector from the initial feature set. Finally, the rough set method extracts a minimal set of decision rules, which will be implemented in the automotive glass inspection system to increase the accuracy and to decrease the rate of false alarms.

2. Automotive inspection system and defects on a backlight

A backlight has a circuit with several conductor lines to eliminate frost. An uneven paint or a scratch on a conductor line (heated conductor lines are observed as white lines on an IR image) causes a defect known as a hotspot or a missing line, as shown in Fig. 1. A hotspot eventually becomes a missing line.

An IR camera based inspection system has been developed to capture and analyze the IR image [2]. The system consists of a power unit, an image acquisition unit, and a computation unit. When a backlight arrives at the inspection system, the backlight is heated for a predefined duration. Then, the IR image is captured by the camera and transferred to the computer. Finally, the image is analyzed by the inspection routine (Fig. 2).

3. Rough set theory

Data is occasionally expressed in a decision table, where each row represents an object, and each column represents an attribute. A decision table is denoted by $S = (U, A \cup \{d\})$, where U is a universe of objects, and A and $\{d\}$ are a set of independent and dependent attributes, respectively.

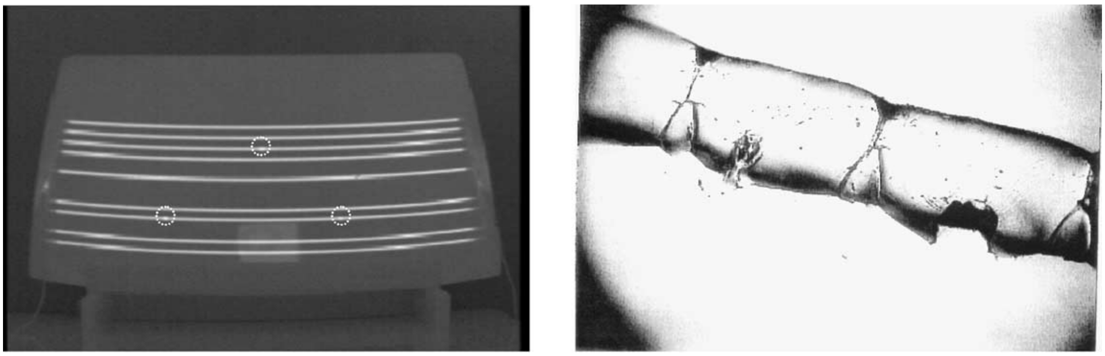

Fig. 1. Two major defects shown on an IR image of backlight: (a) defective backlight with three hotspots and five missing lines; (b) magnified image of a hotspot.