IDEA

Innovations Deserving
Exploratory Analysis Programs

Highway Program

Automated Real-Time Pavement Crack Deflection/Classification System

Final Report for NCHRP-IDEA Project 81

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INNOVATIONS DESERVING EXPLORATORY ANALYSIS (IDEA) PROGRAMS
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Abstract

Pavement distress detection and analysis is an important component of pavement management systems. Conventional visual and manual pavement distress analysis techniques are very costly, time-consuming, dangerous, labor-intensive, tedious, and subjective, have a high degree of variability, are unable to provide meaningful quantitative information, and almost always leading to inconsistencies in distress detail over space and across evaluations. In this project, a novel system for multipurpose automated real-time pavement distress analysis based on CVPRIP (Computer Vision, Pattern Recognition & Image Processing) technologies is presented.

The preliminary results have demonstrated that the proposed system can detect & classify cracks correctly and effectively. The main advantages of the proposed method are:

i. Correctly identify thin cracks even from very noisy images,
ii. Distinguish cracks from shadows,
iii. Necessary parameters can be determined automatically,
iv. Efficiency and accuracy of the proposed algorithm are superior,
v. Detect/classify cracks taken under variable light conditions.

The proposed system can provide high data acquisition rates; effectively and accurately identify the type, severity and extent of surface distress; improve the safety and efficiency of data collection; offer an objective standard of analysis and classification of distress; help identify cost effective maintenance and repair plans; provide images and examples through information highway to other user/researchers; and provide image/sample bank for training or as the benchmark for testing new algorithms. The proposed system can also contribute to other research in pavement maintenance, repair and rehabilitation.

I. INTRODUCTION

Statistics published by the Federal Highway Administration indicates that maintenance and rehabilitation of highway pavements in the United States requires over $17 billion dollars a year. Currently, maintenance and repairs account for nearly one-third of all federal, state, and local government road expenditures. According to the U.S. Department of Transportation (DOT), more than $ 315 billion dollars will be needed through the year 2000 to maintain current road conditions [1].

The collection of pavement surface condition data is usually performed by conventional visual and manual pavement crack analysis approaches, which are very costly, time-consuming, dangerous, labor-intensive and subjective. These approaches have high degree of variability, are unable to provide meaningful quantitative information, and almost always lead to inconsistencies in distress cracking details over space and across evaluations [2].

Pavement monitoring and evaluation are essential requirements for effective pavement management. An automated crack detection system should ideally detect all types of cracking, and other surface distress, of all sizes and at any collection speed. It should be affordable, easy to operate, and capable of daylight operation. Pavement management programs would benefit from devices that provide meaningful, repeatable distress ratings to sections of pavement, and provide critical information for maintenance decisions [3-6]. Many researchers have focused their attentions on automated pavement cracking detection/classification [7-17].

Problems with the existing automated distress detection systems/methods are:

1. Special equipment is required (special lights, laser, etc.) increasing cost and limiting the application of the systems/methods.

2. Existing systems have very low processing speed/low accuracy.

3. Only can identify/process certain crack categories. If additional crack categories or types are desired, the complexity of the system would increases greatly or become unacceptable.

4. Existing Systems cannot achieve real-time processing. Some systems only perform real-time recording (on film or VCR tape), then perform off-line processing and analysis. In some cases, many recorded tapes were stored, but never processed.

II. OBJECTIVES AND MAJOR TASKS

An ideal automated crack detection system should detect. An ideal automated crack detection system should detect all types of cracks, and other surface distress, of all sizes and at any collection speed. This automated crack detection system should be affordable, easy to operate, and capable of operation in variable daylight conditions. Pavement management programs would benefit greatly from devices or systems which give meaningful, repeatable distress ratings to sections of pavement, and provide critical information for maintenance decisions [1-3, 12].

2.1 Objective

The main objective of this study is to develop an automated real-time pavement detection/classification system that can:

1. Provide high data acquisition rates;

2. Improve the safety and efficiency of data collection;

3. Offer objective, accurate and effective analysis and classification of cracks;

4. Help identify cost effective maintenance and repair plans;

5. Provide image/sample bank for training or as the benchmark for testing new algorithms;

6. Provide images and examples through information highway to other user/researchers;

7. Provide pavement conditions of both highways and local roads;

8. Greatly reduce the cost for maintenance/repair;

9. Contribute to other research in pavement maintenance, repair and rehabilitation;

10. Become integrated into the pavement management system.

2.2 Major Tasks

- Investigate the existing approaches and systems, and modify/develop the main procedures of the proposed system.

- Study and develop high-speed algorithms for crack detection/classification, feature extraction, Hough transformation, morphology, etc.

- Test and examine different types of classifiers, and propose new classifier-based experiments.

- Verify and validate the algorithms and the proposed system and conduct road experiments. The experimental results will be used for adjusting/modifying the design, and for developing the prototype.

III. ACCOPLISHMENTS AND SIGNIFICANT FINDINGS

With the support from TRB and UDOT, the PI and four graduate students have conducted this study closely with the engineers of UDOT. The above objectives were achieved and the major were finished.

3.1 Universal Criteria Are Needed

An important goal for this system is to establish an objective, accurate and effective criterion/standard. We have tried to find universal/unified criteria from related publications including the

civil engineering publications, and we found that different groups use different criterion for crack quantification and classification. For instance, when determining the severity of longitudinal cracks, one group used a mean width [18], one another group used the area of the crack, and another used the ratio of the crack area over the area of the entire image.

Another problem is that how small the cracks should be handled. What is the minimum threshold at which a crack is included in the analysis? In [18], for the longitudinal cracks, the severity is measured as Fig. 1. This method gives only the upper bound for low severity cracks (6 mm) and does not indicate the lower bound for detection. This problem occurs with other types of cracks as well. Fig. 2 shows the methodology for measuring the severity of transversal cracks

One group used 3 mm for the minimum threshold, and another group used 5 mm for the minimum threshold size. Currently, our system uses 2 mm as the criterion. We will work with the engineers of UDOT to acquire more pavement images with a much wider range of crack widths.

3.2 Fast & Accurate Processing Algorithm

Development of very fast and accurate algorithms based on CVPRIP (computer vision, pattern recognition & image processing) techniques is the key goal for this study. We have processed over 20,000 crack images and compared the results with human observations. Of interest is a field test conducted on a segment pavement, and compared the results of the system with those obtained by the engineers of UDOT. The results confirmed that the proposed system accuracy is over 97%. If one considers human error and subjectivity, the accuracy could be considered even higher. The proposed system can be used to establish objective criteria for pavement crack detection/classification.

3.3 Adaptability and Robustness

The algorithms of a good automated real-time pavement crack detection/classification system have to have the adaptability and robustness since pavement images are inherently very noisy, fuzzy and blurry. Images may be taken at different speeds, of different types of pavements, and under different lighting conditions.

Pavement images have been analyzed with the vehicle speeds ranging from 35 mph to 75 mph, at 10am and 4pm (shadows), on sunny and cloudy days. The high accuracy demonstrates the adaptability and robustness of the proposed system.

3.4 Update-Capability

The proposed system works under different environmental conditions and can be adjusted for any pavement type (including future development). Due to the rapidly increasing computational power of PC's, the developed system and accompanying data should be transferable to new operating systems and hardware easily.

We have processed images from different sources, and the system works very well. The system has the flexibility to be adjusted to the users' special specifications as well.

IV EXPERIMENTAL RESULTS

We have tested more than 20,000 images (Figures 3-13), and show some results (note: The image size is 640 X 480) as below.

Fig. 3(a) very bright image asphalt pavement with mean intensity value = 206.1, and (b) resulting image
Fig. 4(a) dark image of a concrete pavement with mean intensity value = 125.8, (b) the resulting image.
Fig. 5(a) concrete pavement slightly brighter than the one in Fig. 4(a), with mean intensity = 136.5, and (b) the resulting image.
Fig. 6(a) very noisy image of an asphalt pavement with mean intensity value = 163.5, and (b) the resulting image.

Fig. 7(a) shows another very noisy image of an asphalt pavement with mean intensity value = 152.6, and (b) corresponding resulting image.
Fig. 8(a) is a very dark image of an asphalt pavement with mean intensity value = 117.6 and (b) is the resulting image.
Fig. 9(a) is another dark image with mean intensity value = 116.9 and (b) is the resulting image.
Fig. 10(a) bright image (mean intensity value = 174.7) with alligator cracking, and (b) is the resulting image.
Fig. 11(a) dark image (mean intensity value = 121.6) with alligator cracking, and (b) is the resulting image.
Fig. 12(a) is an extremely dark image (mean intensity value = 64.7), and (b) is the resulting image.
Fig. 13(a) is an image with shadow, and (b) is the result.

From the above experiments, it can demonstrated that the proposed system can process images of different types of pavements, under varying light conditions, and can handle shadows i.e., the system has the adaptability and robustness required.

V. FURTHER DEVELOPMENT

- Collect more pavement images with greater variability of resolution, speeds and lighting.
- Integration of the system with a GPS device.
- Use digital video camera, (currently, we are using a SVGA camera bought more than 10 years ago), new PC with higher processing speed (currently, a 1 GHz PC), and we hope to improve the accuracy by developing even a more robust processing algorithm.
- Articles related to this project will be published.
- Establish objective and universal criteria for crack detection/classification by collaborating with other researchers and engineers.
- Install a vehicle with the proposed system, conduct field tests to verify the performance of the proposed system, and make the system available for the users.

VI CONCLUSIONS

We have studied a novel system for automated real-time pavement distress detection based on CVPRIP technologies. The experimental results have shown the efficiency and effectiveness of the proposed system. This system can:

- Provide high data acquisition rates; effectively and accurately identify the type, severity and extent of surface distress
- Improve the safety and efficiency of data collection
- Offer an objective standard of analysis and classification of distress
- Help identify cost effective maintenance and repair plans
- Provide images and examples through information highway to other user/researchers
- Provide image/sample bank for training workers, or other devices, or as the benchmark for testing new algorithms.

The proposed system will be useful for pavement management.

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4. LONGITUDINAL CRACKING

Description

Cracks predominantly parallel to pavement centerline. Location within the lane (wheel path versus non-wheel path) is significant.

Severity Levels

LOW

A crack with a mean width ≤ 6 mm (0.25 in.); or a sealed crack with sealant material in good condition and with a width that cannot be determined.

MODERATE

Any crack with a mean width ≥ 6 mm (0.25 in.) and ≤ 19 mm (0.75 in.); or any crack with a mean width ≤ 19 mm (0.75 in.) and adjacent low severity random cracking.

HIGH

Any crack with a mean width > 19 mm (0.75 in.); or any crack with a mean width ≤ 19 mm (0.75 in.) and adjacent moderate to high severity random cracking.

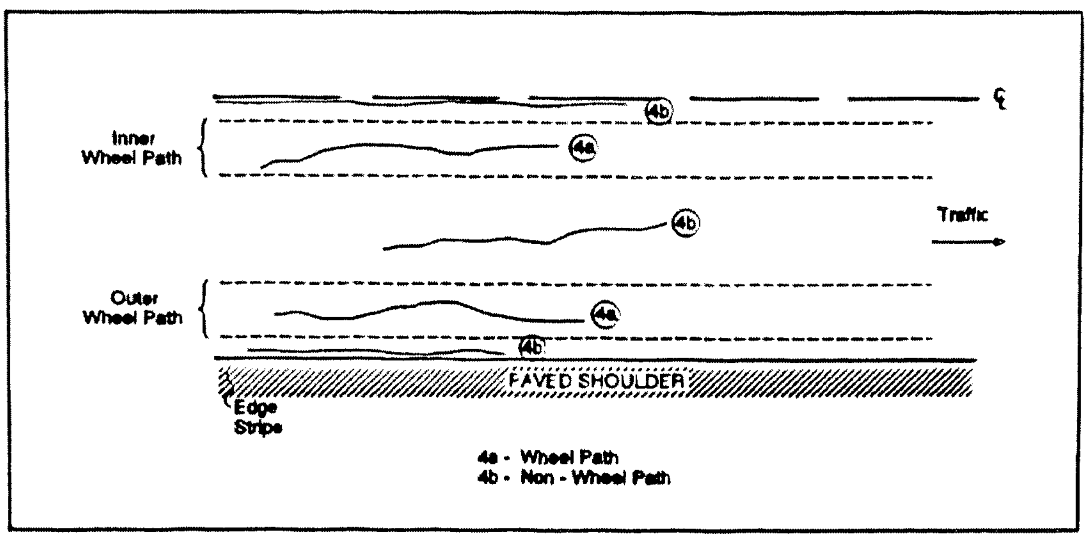

Fig. 1. Longitudinal cracks and their severities

TRANSVERSE CRACKING

Description

Cracks that are predominantly perpendicular to pavement centerline, and are not located over portland cement concrete joints.

Severity Levels

LOW

An unsealed crack with a mean width ≤ 6 mm (0.25 in.); or a sealed crack with sealant material in good condition and with a width that cannot be determined.

MODERATE

Any crack with a mean width > 6 mm (0.25 in.) and ≤ 19 mm (0.75 in.); or any crack with a mean width ≤ 19 mm (0.75 in.) and adjacent low severity random cracking.

HIGH

Any crack with a mean width > 19 mm (0.75 in.); or any crack with a mean width ≤ 19 mm (0.75 in.) and adjacent moderate to high severity random cracking.

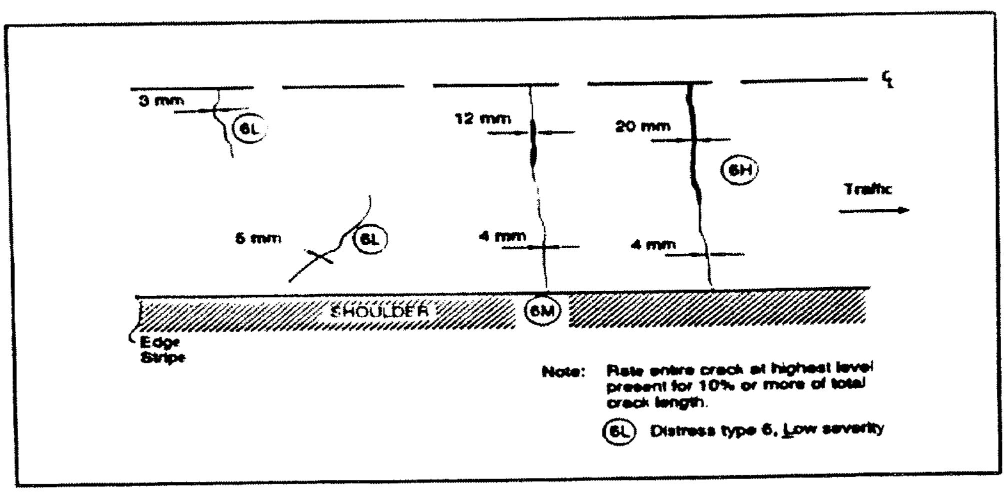

Fig. 2. Transverse cracks and their severities

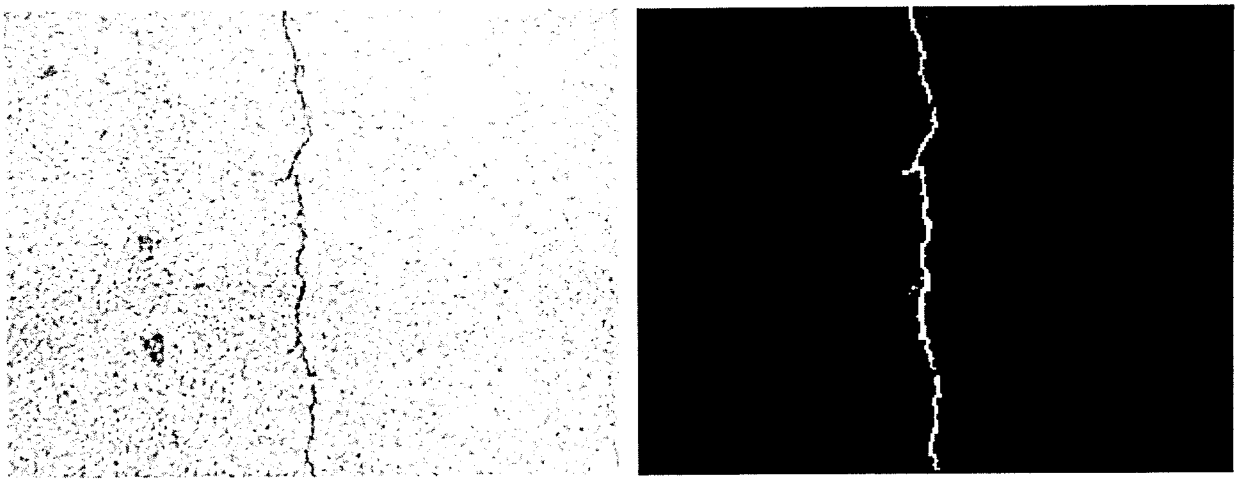

Fig. 3 (a) A brighter image (b) The result

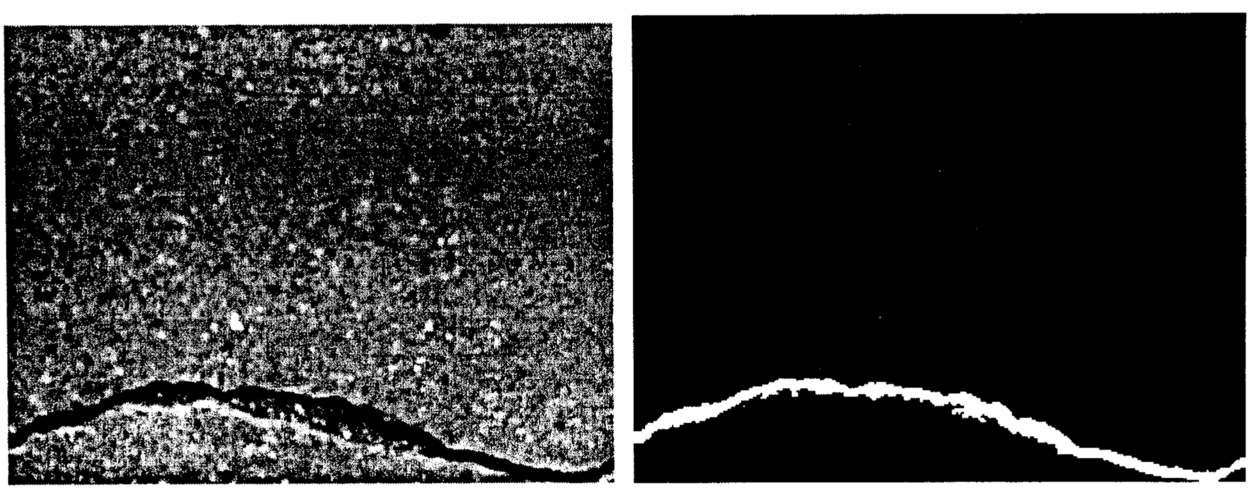

Fig. 4(a) A darker image. (b) The result

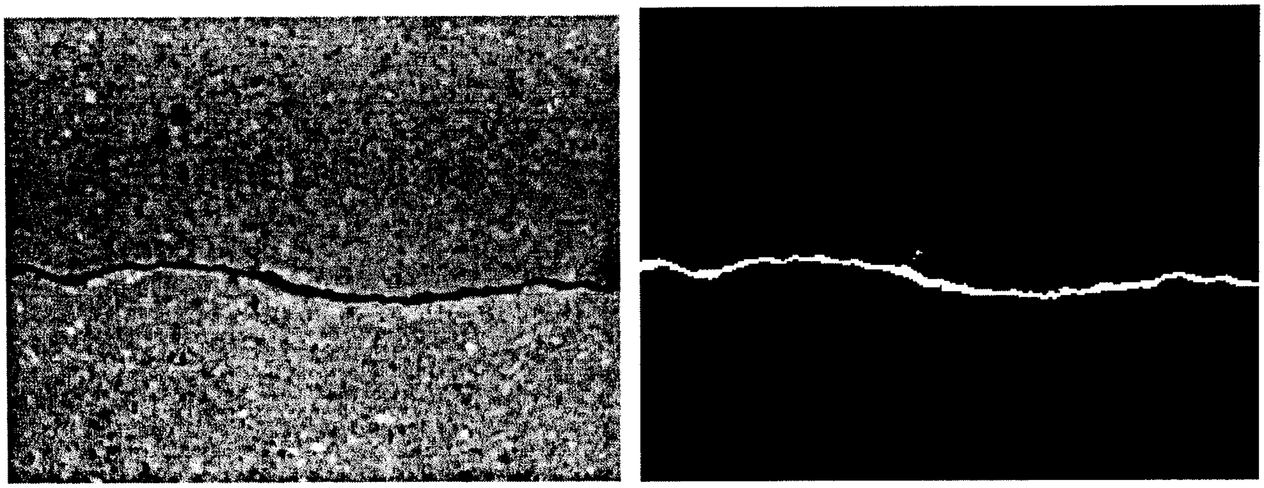

Fig. 5(a) An image slightly brighter than the one in Fig. 4(a),
(b) The result

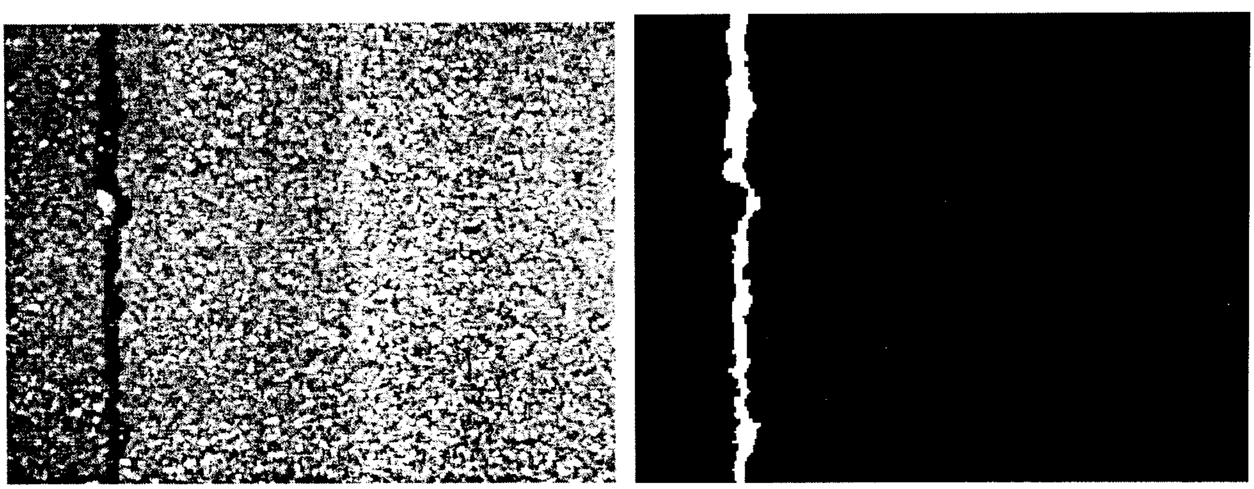

Fig. 6(a) A very noisy image, (b) The result

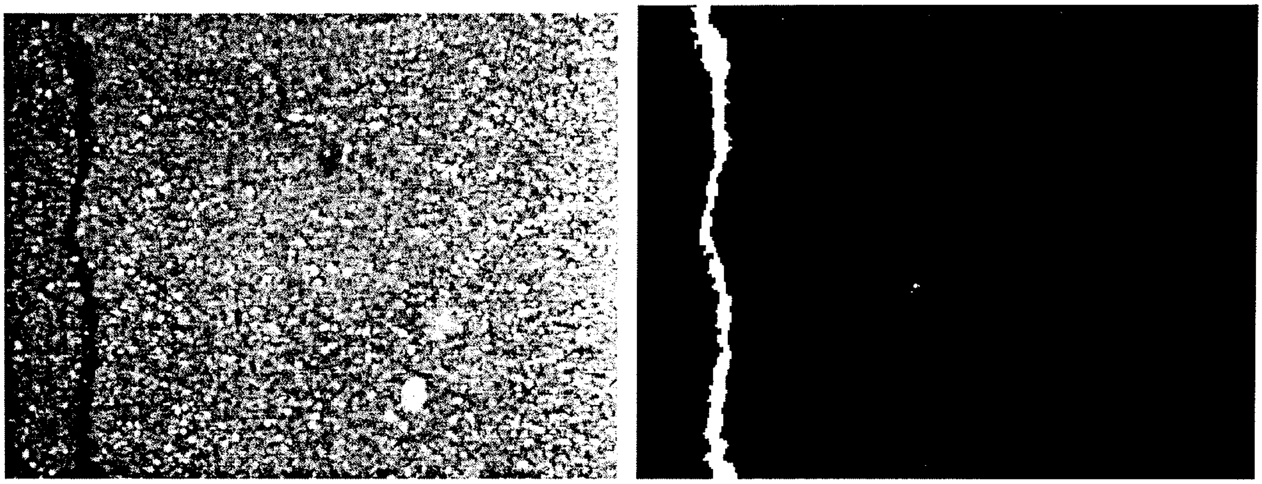

Fig. 7(a) Another noisy image, (b) The result

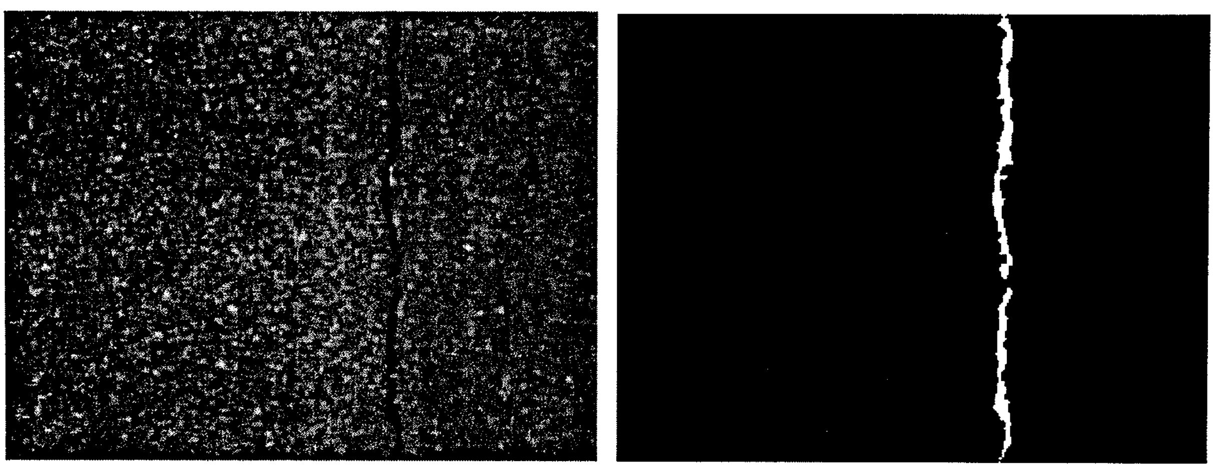

Fig. 8(a) A darker image, (b) The result

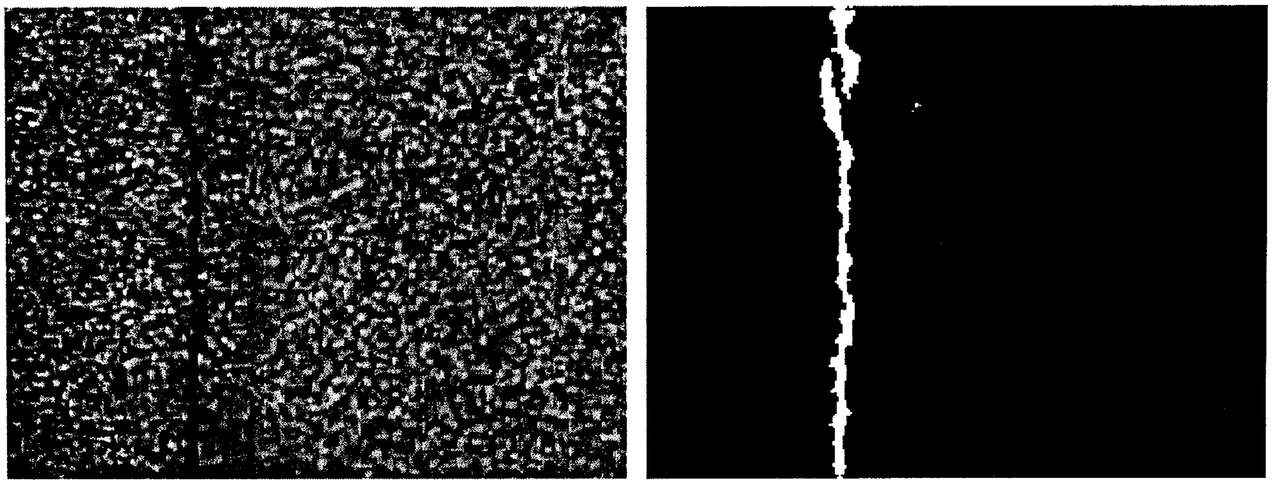

Fig. 9(a) A darker image, (b) The result

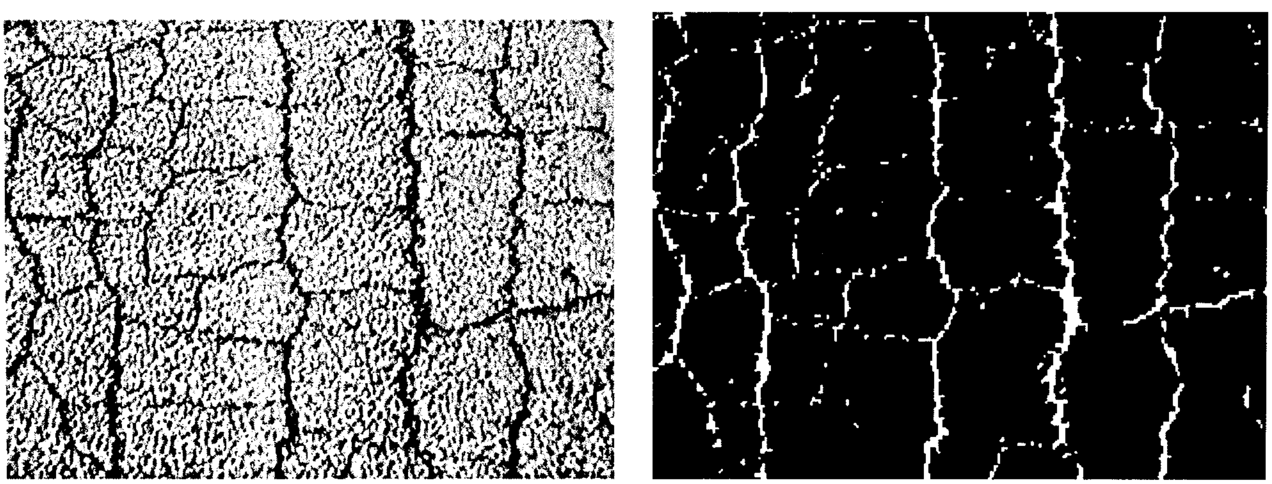

Fig. 10(a) A brighter image with alligator crack, (b) The result

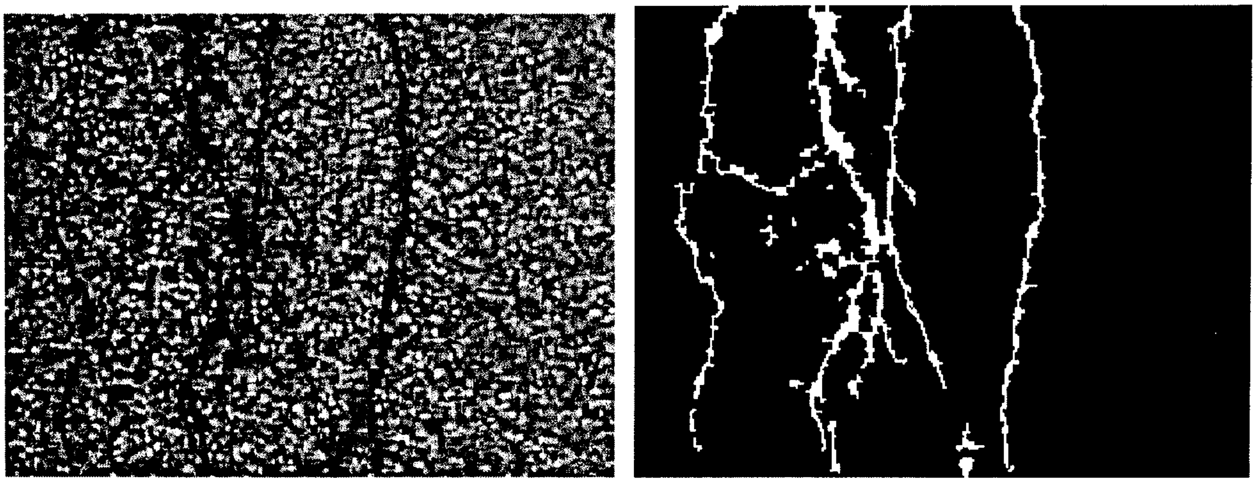

Fig. 11(a) A darker image with alligator crack, (b) The result

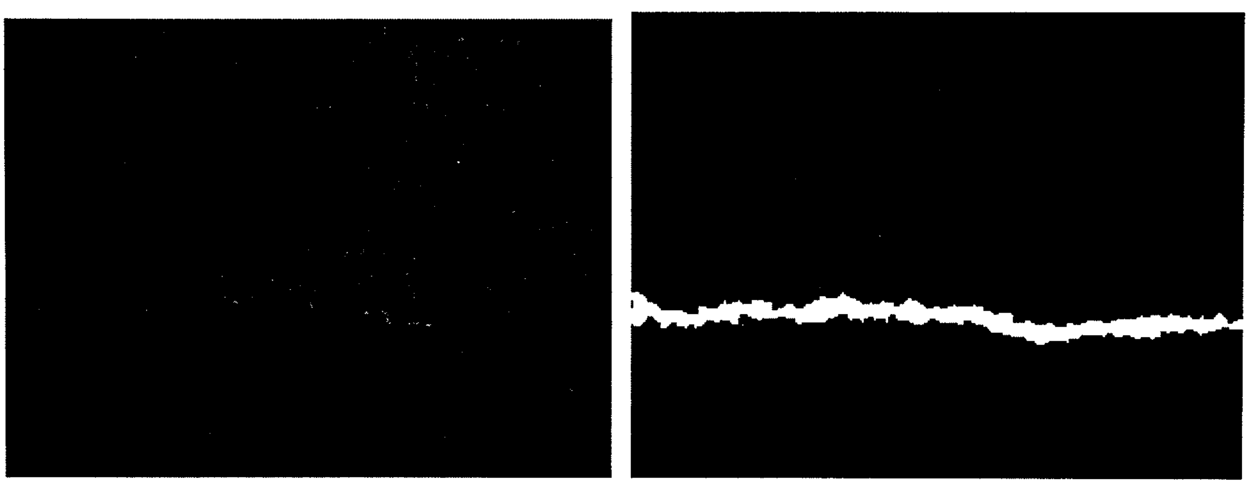

Fig. 12(a) An extremely dark image, (b) The result

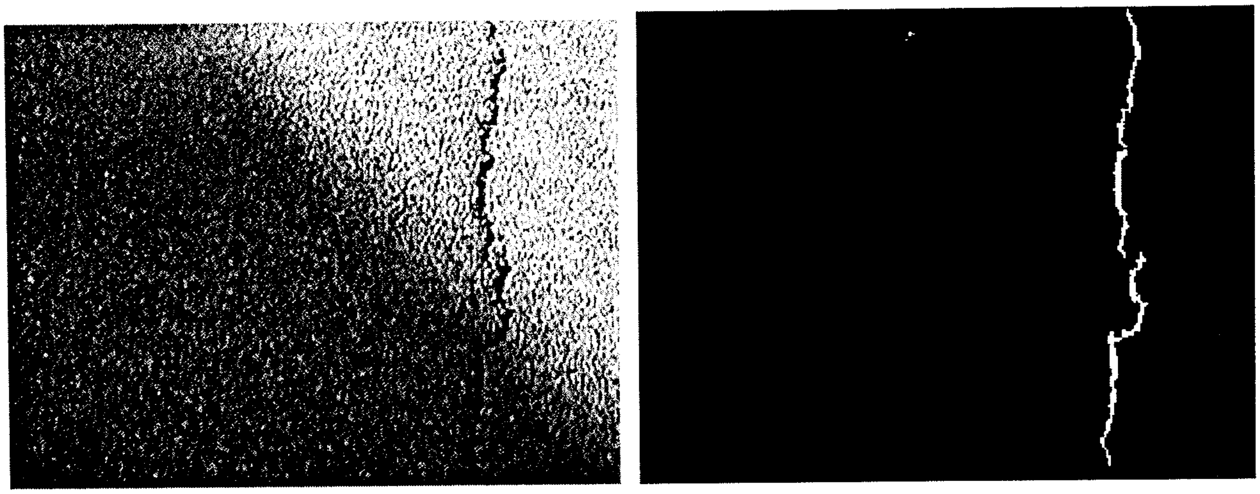

Fig. 13(a) The image with shadow, (b) The result