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RESEARCH ON DEFECT DETECTION OF PRINTING SURFACE

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Abstract. *This study aims for the improvement of automatic vision defect inspection systems making them more capable of effectively detecting defects on painting surfaces. Factories need to detect defections on the production line automatically in order to improve production quality and enhance productivity. The reflection of the painting surface is much stronger than that of a processed surface but weaker than a chrome-plated mirror surface. Besides, since the defects on the painting surface are various and the different defects have different features, it is impossible to use one algorithm to deal with all types of defects effectively. In this study, an automatic moving platform has been used to simulate the production and make the defects clear by taking photos from different locations. Then a series of images of one painting surface can be used in the follow-up processing. In addition, different algorithms are used to detect the defects and studied to find out which algorithm is better for detecting particular kind of defects. When there is a range of differing defects, they are detected more effectively by using the proposed matched algorithm. Finally, the presented automatic vision defect inspection system was implemented and tested on a series of painting surfaces. Encouraging experimental results show that this method is effective.*
Keywords: Defect detection, Painting surface, Image processing

1. **Introduction.** With the development of automatic production line, the automatic detection system is highly desired. However, at present there is no automatic detection system that can satisfy all the requirement and the factories have to detect the defects by human inspectors. It is hard work and the more time workers spend, the lower effectiveness of detection is. In this paper, edge detection [1] and corner detection [2] are used to find defects on the printing surface. The edge detection includes a variety of mathematical methods that aim at identifying points in a digital image at which the image brightness changes sharply. The points at which image brightness changes sharply are typically organized into a set of curved line segments termed edges. The same problem of finding discontinuities in one-dimensional signals is known as step detection and the problem of finding signal discontinuities over time is known as change detection. Edge detection is a fundamental tool in image processing, machine vision and computer vision, particularly in the areas of feature detection and feature extraction. The purpose of detecting sharp changes in image brightness is to capture important events and changes in properties of the world. It can be shown that under rather general assumptions for an image formation model, discontinuities in image brightness are likely to correspond to: discontinuities in depth, discontinuities in surface orientation, changes in material properties and variations in scene illumination [3, 4].

In the ideal case, the result of using an edge detector to an image may lead to a set of connected curves that indicate the boundaries of objects, the boundaries of surface markings as well as curves that correspond to discontinuities in surface orientation. Thus, applying an edge detection algorithm to an image may significantly reduce the amount of data to be processed and may therefore filter out information that may be regarded as less relevant, while preserving the important structural properties of an image. If the edge detection step is successful, the subsequent task of interpreting the information contained in the original image may therefore be substantially simplified.

The edges extracted from a two-dimensional image of a three-dimensional scene can be classified as either viewpoint dependent or viewpoint independent. A viewpoint independent edge typically reflects inherent properties of the three-dimensional objects, such as surface markings and surface shape. A viewpoint dependent edge may change as the viewpoint changes, and typically reflects the geometry of the scene, such as objects occluding one another. That is the reason why images from different places are used in this study.

Corner detection is an approach used within computer vision systems to extract certain kinds of features and infer the contents of an image [2]. Corner detection is frequently used in motion detection, image registration, video tracking, image mosaicking, panorama stitching, 3D modeling and object recognition. Corner detection overlaps with the topic of interest point detection. A corner can be defined as the intersection of two edges. A corner can also be defined as the points for which there are two dominant and different edge directions in a local neighborhood of the points. In practice, most so-called corner detection methods detect interest points in general, and in fact, the term "corner" and "interest point" are used more or less interchangeably through the literature.

Although the edge detection focuses on the points which brightness changes sharply and the corner detection focuses on the "interesting points", both of these are used to extract features of images in essential. We try to use both of these two methods together in this research because we aim to combine the preponderances of the edge detection and the corner detection and by this way the system can exploit the accuracy to the full.

There are many reasons that may cause the defects and there are many different kinds of defects on the printing surface. Three frequent defects on the printing surface and the features of these defects are as follows. Researching the features of the defects can lay a foundation for the further detection and extraction.

1) Surface scratch: The scratches on the printing surface are usually caused by the human factor after the printing process. The width of those scratches is about 0.1 [mm] and the length or form is irregular. Those scratches can only be seen at some special angle and are hard to be detected.
2) Surface bulge: This kind of defect is relatively obvious and seems like particle on the printing surface. The reasons that cause this defect include local abnormal deformation during sheet metal stamping; the plate is not clean enough before entering the printing process.
3) Surface dirt: This defect is mainly because of other paint or the dirt from the environment.

The above defects maybe appear in any position on the painting surface. Influenced by the factory environment and production process, the automatic detection system can only be installed before the package procedure and in that time the assembly process has finished.

In this study, an automatic moving platform is used to simulate a production line and operated with an image capture device to make defects clear by taking photos at different locations. Then a series of images of one painting surface can be used in the follow-up processing. In addition, edge detection and corner detection are used to detect the defects. Finally, the presented automatic vision defect inspection system was implemented and tested on a series of painting surfaces.

2. A New Defect Detection Method of Printing Surface.

2.1. Review of related research.
In recent years, there have been many researches about defect detection on highly reflective surfaces, such as machined surfaces, painted surfaces, and plated surfaces. Jia et al. [5] proposed a real-time visual inspection system that uses support vector machine (SVM) to automatically learn complicated defect patterns. Based on the experimental results generated from over one thousand images, the proposed system is found to be effective in detecting steel surface defects. However, a reflection of painted surface is stronger than steel meaning that the noise has also been increased. So this method is not effective to use for painted surfaces. Iivarinen [6] proposed two histogram-based texture analysis techniques for surface defect detection. These techniques are the co-occurrence matrix method and the local binary pattern method. Both methods yield a set of texture features that are computed from a small image window. The unsupervised segmentation procedure is used in the experiments. It is based on the statistical self-organizing map algorithm that is trained only with fault-free surface samples. However, this method is not suitable for some kinds of defects such as a blot or scratch because the LBP feature can only deal with the relationship between one pixel and its surrounding, so it is difficult for LBP to extract the feature of a blot or scratch for due to their relatively large size. Zhou et al. [7] proposed a practical machine-vision-based system for fast detection of defects occurring on the surface of bottle caps. This system can be used to extract the circular region as the region of interests (ROI) from the surface of a bottle cap, and then use the circular region projection histogram (CRPH) as the matching features. However, this method is more sensitive to changes in light and in painting density. The algorithm should be improved so that it is robust to changes in brightness and painting density.

On the other hand, authors in [8] designed an automatic vision defect inspection system for plated surfaces which has been proved to be effective. In our application, the inspection system is in a dark room and the object is fixed properly on the work piece. In order to remove the specular reflection, four (or more) images are generally captured from the object illuminated by four different incidence directions in turn, and then the specular processing procedure is performed. This inspection system works well for defect detection of the plated surfaces. However, it also has a drawback, being that the object needs to be fixed properly on the work piece and requires time to obtain four (or more) images. Therefore, in this study, in order to overcome the drawback noted above, a new defect detection method has been proposed and described in the next section.

2.2. A new defect detection method of printing surface.
In this section, we plan to use both the edge detection and corner detection to detect the printing surface. A processing flowchart is shown in Figure 1. As is shown in Figure 1, in image processing, to smooth one image is to create an approximating function that attempts to capture important patterns in the image, while leaving out noise. In smoothing, the pixels points of one image are modified so individual points are reduced, and points that are lower than the adjacent points are increased leading to a smoother image. Smoothing may be used in two important ways that can aid in data analysis by being able to extract more information from the data as long as the assumption of smoothing is reasonable and by being able to provide analyses that are both flexible and robust [9].

Many different algorithms are used in smoothing. In this paper, Gaussian smoothing is used. Gaussian smoothing is the result of blurring an image by a Gaussian function. It is a widely used effect in graphics software, typically to reduce image noise and reduce detail. Mathematically, applying a Gaussian smoothing to an image is the same as convolving the

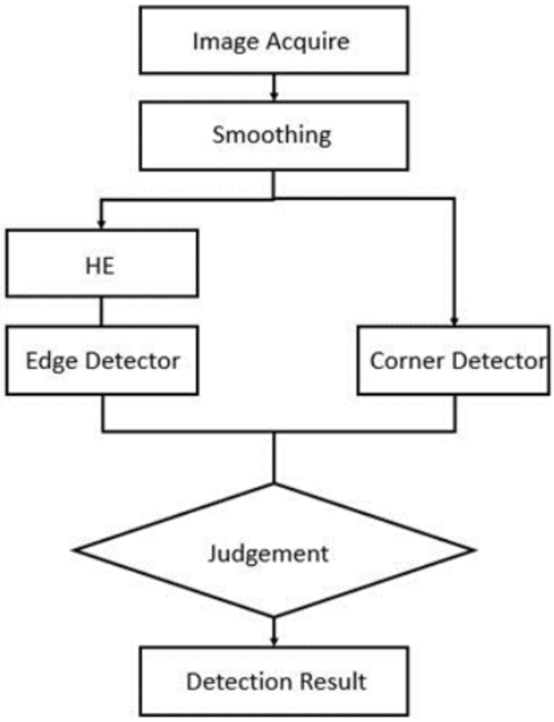
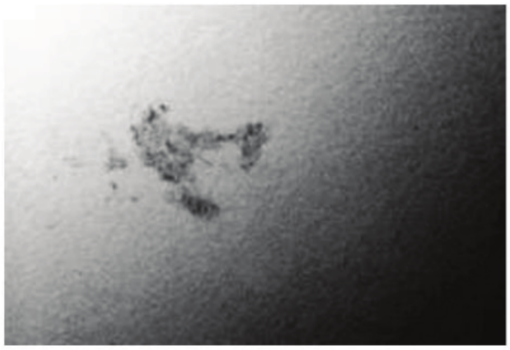


Figure 1. Detection method

(a) Original image with a dirt



(b) Result of histogram equalization

Figure 2. Example of the defect image before and after histogram equalization

image with a Gaussian function. Choosing a right size Gaussian kernel is a key point. The low dimension Gaussian kernel means saving more details of image together with noise. The high dimension Gaussian kernel means de-noising well but maybe losing a part of information. So after a series of tests, we find out the use of a 3-dimension Gaussian kernel is effective.

Contrast enhancement is the base of image processing and has a huge influence on the further detection. In this paper, histogram equalization is used to enhance the contrast. This method usually increases the global contrast of many images, especially when the usable data of the image is represented by close contrast values. Through this adjustment, the intensities can be better distributed on the histogram. This allows for areas of lower local contrast to gain a higher contrast [10]. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values. Figure 2 shows the results example of histogram equalization, where (a) shows the original image with a surface dirt and (b) shows the result of histogram equalization. By comparing figures (a) and (b) of Figure 2, it can be seen that the contrast of (b) is much stronger than that of (a) and the defect on the (b) is much more obvious. Besides, although there are three kinds of defects, the histogram equalization is the same.

After preprocessing, both edge detection and corner detection are used to extract defects characteristics existing on the painting surface. Finally, the judgment is achieved by two processing: template matching and recognition, using two images obtained from a moving object, where template matching is a processing that subtracts the sample image from the template image, which does not include any defect. After template matching was processed for the two images, recognition is carried out by comparing two images obtained. If there is arbitrary one in two images where gray value is not zero, then a defect in probability can be judged. In the opposite case, there is no defect.

3. **Experiment Result and Discussion.**

3.1. **Detection testbed.** This automatic detection testbed is derived from the authors automatic vision inspection system [8] and some changes are made to fit the detection object. With the previous defect inspection, four images are generally captured from the object illuminated by four different incidence directions in turn in the image acquisition stage. This previous detection system uses four light sources at different angles and takes pictures for the fixed detection objects. However, a painting surface automatic detection system would be used on a production line where the detection object would be moving. Some defects on the painting surface are so obscure that they can only be seen at some special place and angle. Furthermore, the previous detection system needs a relatively long time to gain four images. So in this study, we modify the previous detection system and show it in Figure 3. As shown in Figure 3, the improved detection system has just one light source and an automatic mobile platform is added. That improved detection system is based on the previous detection system, just reducing three light sources and adding one mobile platform. The detection object can be fixed on the mobile platform in order to simulate the moving production line.

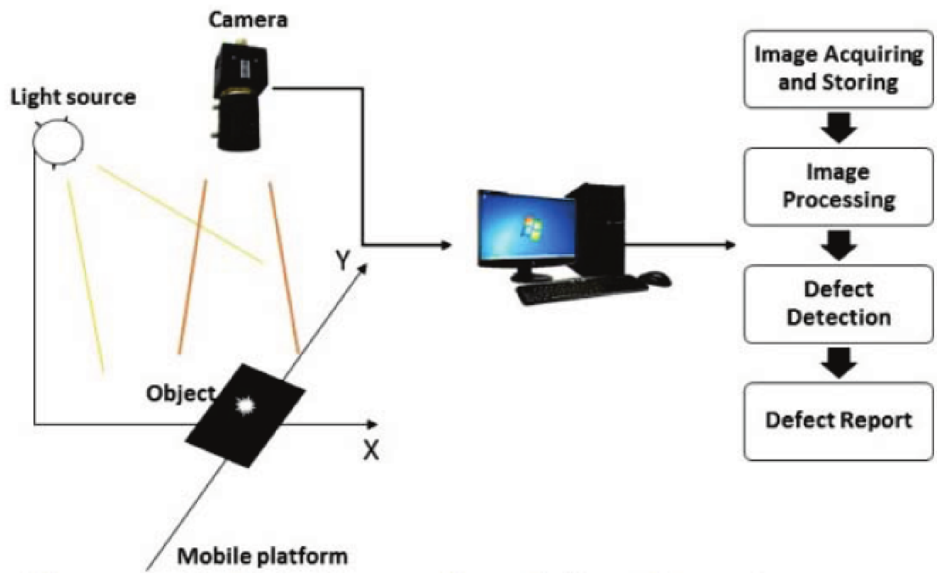
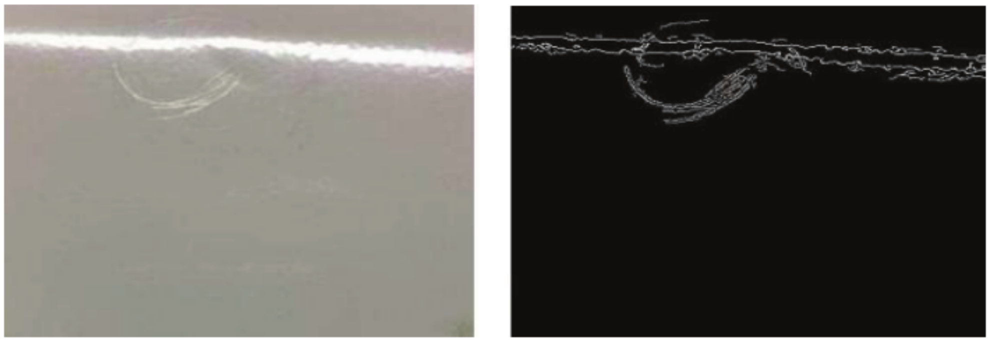


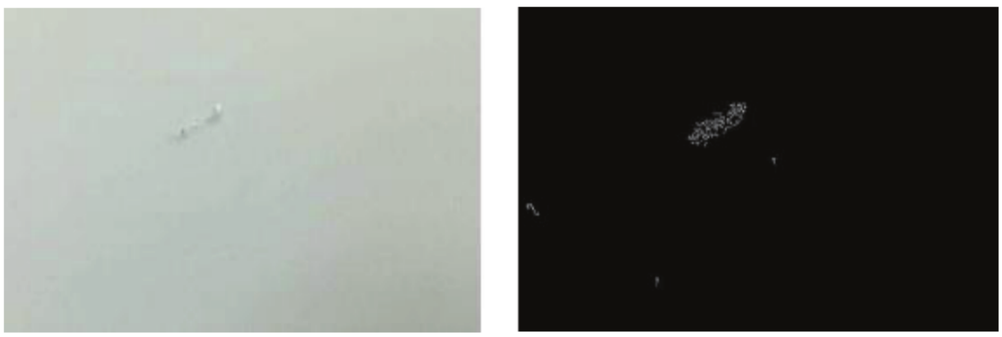
Figure 3. Printing surface defect detection system

3.2. **Result and discussion.** There are many edge detection operators and in this paper a Canny edge detection operator has been used. The Canny edge detection is a technique to extract useful structural information from different vision objects and dramatically reduce the amount of data to be processed [11]. Among the edge detection methods developed so far, the Canny edge detection algorithm is one of the most strictly defined methods that provides good and reliable detection. Through the experiment, we find that the Canny edge detector is effective for surface scratch and surface bulge. Figure 4 and Figure 5 show the results of detection using the Canny operator, where (a) show the original images and (b) show the results of detection using the Canny operator, respectively.



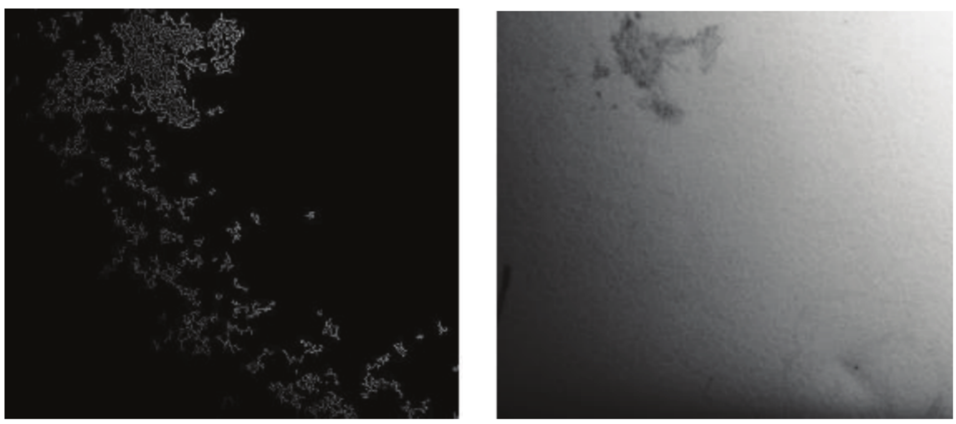
(a) Original image with a scratch (b) Detection result

Figure 4. Example of the surface scratches detection result using the Canny edge detector



(a) Original image with a bulge (b) Detection result

Figure 5. Example of surface bulge detection result using the Canny edge detector



(a) Detection result (b) Original image with a dirt

Figure 6. Example of the surface dirt detection result using the Canny edge detector

However, the Canny edge detector is not suitable for surface dirt as shown in Figure 6. So, next we use the corner detector to deal with that defect. A corner can be defined as the intersection of the two edges. And a corner can also be defined as a point for which there are two-dominant and different edge directions in the local neighborhood of the point. In practice, most so-called corner detection methods detect interest points in general, and in fact, the terms "corner" and "interest point" are used more or less interchangeably throughout [2]. As shown in Figure 7, we gain the shape of dirt by fitting the corner points and calculate the area of dirt by the number of corner points.

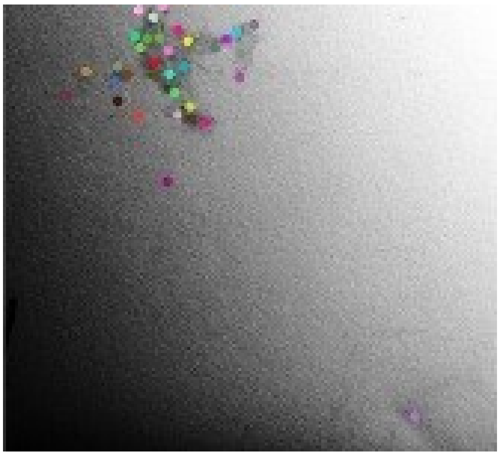
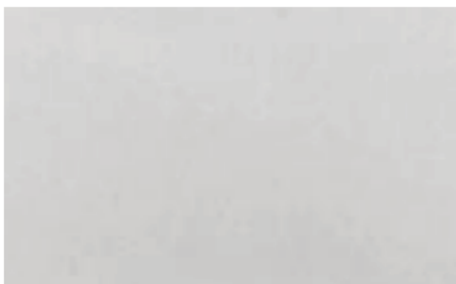


Figure 7. Example of surface dirt detection result using corner detection

In this study, we use the template matching method, which is to subtract the defects images from the template image that is the image of painting surface without defect. Through this process, we can find the defects characteristic on the painting surface. We use surface dirt defect image after corner detection as an example to show this process. Figure 8(a) shows the example of the dirt defect image after corner detection image processed by corner detection and (b) shows the template image. Then, we subtract the defect images from the template image and the example of the result obtained is shown in Figure 9. As shown in Figure 9, the gray value of the image obtained by template matching is not zero, that is, the defect's characteristic has been extracted.

Finally, recognition processing is carried out by comparing the two images obtained by the template matching, where the two original images are obtained from a moving object, which are measured by using the detection testbed shown in Figure 3. Figure 10

(a) Dirt image after corner detection



(b) Template image

Figure 8. Example of dirt defect image after corner detection and template image

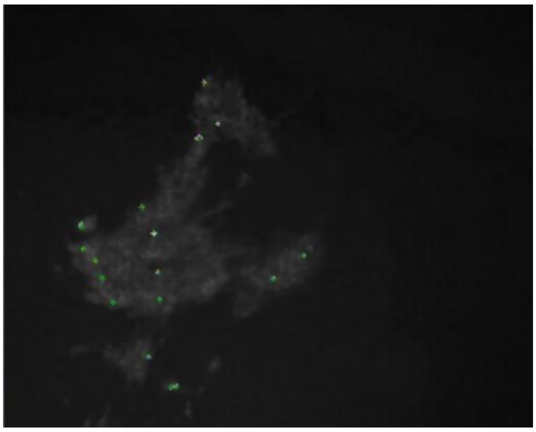


Figure 9. Example of the image after template matching processing

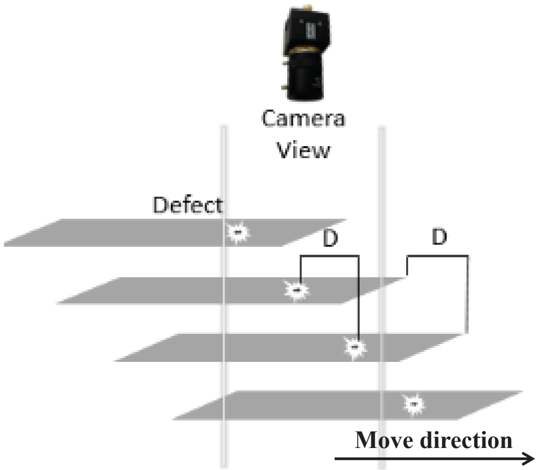


Figure 10. Schematic diagram of defect migration

shows a schematic diagram of defect migration. It can be seen from Figure 10 that the defect moves the same distance each time as object moves, and the images are taken from each object location. Therefore, the defect in each image also moved the same distance as the object moved. The continuous two images within camera view are taken out as a pair for the template matching processing. After the template matching, if there are two images at the same time where gray value is not zero, then a defect in high probability can be judged. In the opposite case, there is no defect. Furthermore, this recognition method was used to three types of defects and all the defects of samples have been judged successfully.

4. **Conclusion and Future Work.** In this paper, a new mobile detection platform is designed and using both of the edge detection and corner detection to detect defects on printing surface. The defect judgment method using the template matching has been proposed and it is effective. However, only three kinds of defects are detected in this paper and there are many other kinds of defects. So more kinds of defects will be detected using this automatic detection system in the future. The features of different kinds of defects will be extracted more precisely by using deep learning.

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