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Surface Defect Characterization in Polishing Process using Contour Dispersion

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Abstract—**Automatic surface defect detection with vision systems can bring manufacturers a number of significant benefits, especially when used on-line. This non-contact method may present an alternative to allow the surface defect to be measured rapidly and with an acceptable accuracy. One of the most promising of the non-contact methods in terms of speed and accuracy is the computer vision technique. This paper basically defines a surface defect characterization using contour dispersion. The basic idea of this research is to find an optimal gray-level threshold value for separating objects of interest in an image from the background based on their gray-level distribution using contour dispersion level to find the characteristic of surface defect. Next, the research direction has been suggested to develop an automatic polishing robot system using vision sensor based on surface defect characterization.**

Keywords – surface defect characterization, polishing process, multilevel thresholding, contour dispersion, scratch and corrosion.

I. INTRODUCTION

As most products are manually inspected after the process has been completed large quantities of sub-standard product may have to be scrapped. Manual inspection for surface defects has a number of drawbacks, including subjectivity, varying standards and high costs. Inspection systems using image processing can overcome many of these disadvantages and offer manufacturers an opportunity to significantly improve quality and reduce costs.

Surface quality is important to a manufacturer as it can affect both the appearance and function of a product. A surface can be considered to be defective if it has scratches or dents, a matt finish when it should be glossy, or a color that does not match other items of the same type. Assessment of each of these types of quality problem requires different inspection techniques and equipment. Reflectivity and color are absolute measurements of appearance, and their values can be given as one or a few numbers.

Automatic surface defect detection systems can bring manufacturers a number of significant benefits, particularly when used on-line. They can help reduce levels of scrap, improve quality, keep a permanent record of product quality and optimize the production process, giving both direct and indirect cost savings and increasing a company's competitiveness.

A local defect can be defined as an area of a surface which has an appearance that does not match that of the surrounding good quality surface. This can be due to a local change in the topology, reflectivity or color of the surface at the location of the defect. Local defects can be of two main types. A defect seen as an area of surface darker or brighter than the area around it can be called a 'contrast defect'. On textured or patterned surfaces there can also be defects which have brightness within the same range as that of the surrounding good quality surface. These defects are visible because of a change in the texture or pattern, and are referred to as 'pattern defects'. Different image processing algorithms are clearly required for the detection of each type [1].

One of preliminary process of local defect is surface characterization. The surface characterization of the defect is a very useful tool in predicting the properties and the quality of the final product. Determining the defect pattern quality at an early stage before others process that can potentially time consuming and money wasting. A number of vision systems, have been developed for detecting surface defect [2], [3], [4], [5]. Most of the work done on the surface quality inspections is high computing time and sometimes hard to implement in real time system. Because of that we need to find the algorithm that suitable to use in real time system.

This research takes a scope on surface defects such as scratches and corrosion that cause major problems for manufacturer especially polishing process in body car industry [6]. The work reported in this paper deals with detection and characterization of defects contained in common metals used in automotive body applications. Steel, cast iron, aluminum, magnesium, copper, zinc, glass, and polymers are the most commonly used materials. In this research SPCC-390 aluminum plate is used as a sample that will be characterized using contour based image analysis based on contour dispersion level methods. The algorithm described in this paper would achieve the simple, fast and easy to use especially in surface defect characterization.

II. LITERATURE REVIEW

The review of image processing algorithms for defect detection, measurement and classification has been done to give comprehensive knowledge about this field. A number of techniques which have been developed for use on a dedicated machine vision for defect detection system are presented and discussed.

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A. Multilevel Thresholding

Segmentation is an essential ingredient in a wide range of image processing tasks and a building block of many visualization environments. One of the powerful segmentation techniques is a multilevel threshold. This technique is a process that segments a gray-level image into several distinct regions. This process is often designed using the gray level histogram of the image. The multilevel threshold technique determines more than one threshold for the given image and segments the image into certain brightness regions, which correspond to one background and several objects. An algorithm that uses a variant of the classification by clustering method is used to compute the optimal values to threshold the image into a number of classes [7].

B. Contour Dispersion

A contour dispersion of a function of two variables is a curve along which the function has a constant value. Contour line for a function of two variables is a curve connecting points where the function has a same particular value. A contour is a set of level curves of different heights of a function of two variables. A level curve of height h of a function f(x,y) is the set of all points (x,y) such that f(x,y) = h. For a well-behaved function, a level curve is typically one or more simple closed curves. The gradient of the function is always perpendicular to the contour lines. When the lines are close together the length of the gradient is large: the variation is steep. If adjacent contour lines are of the same line width, the direction of the gradient cannot be determined from the contour lines alone. In mathematics, a level set of a real-valued function f of n variables is a set of the form :

$$\{(x_1,\ldots,x_n) \mid f(x_1,\ldots,x_n) = c\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where c is a constant that is the set where the function takes on a given constant value. When the number of variables is two, this is a level curve (contour line), if it is three this is a level surface, and for higher values of n the level set is a level hyper-surface. This paper develops 2 dimension level curves that is the set of all real-valued roots of an equation in two variables x1 and x2.

There are a number of methods of having a computer draw contour dispersion, but almost all of them work by numerically approximating the coordinates of a finite number of points on a level curve and plotting a curve that fits these points. The principal differences between the methods are in how the points are approximated and how the curve to fit them is generated. Another difference is whether the function to be contoured is presented as a procedure that computes the function at arbitrary points or as a table of values of the function at a fixed set of points.

III. METODOLOGY

In surface defect characterization, there are some steps that we must do. First is image acquisition that grab image from device (camera). To get the better image and remove the noise from the image, image adjusting and filtering is done. And the last is multilevel threshold and classify the image with contour dispersion to get the feature of surface defect. Here is the explanation of the methodology of our research.

A. Image Acquisition

For the specimen we use SPCC-390 aluminum plate that usually used as a car body component. The color of specimen is silver that makes the light reflect diffusion, and this condition make we could not get the real surface image of the specimen. Because of that we use an extra lighting system with red color that good for gray scale camera. We grab surface defect picture from OMRON F500 Vision System with 1 mega pixel resolution that enables high-precision inspections and measurements that commonly used in factory. We chose the standard image resolution for inspection that is 512x484 (247.808 pixels). Figure 1 shows a picture of vision system that we use in surface defect characterization.

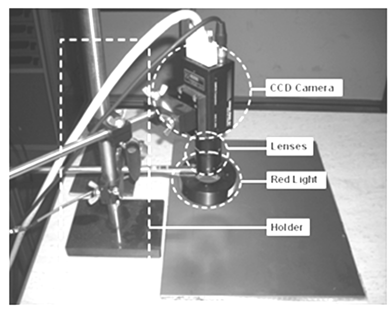
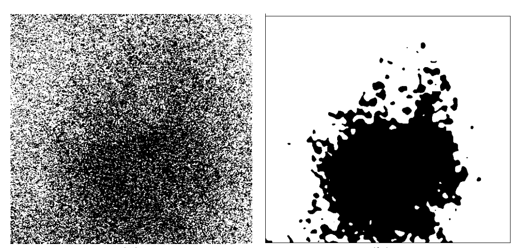


Figure 1. Vision system and sample of image grabbing

B. Image Adjusting and Filtering

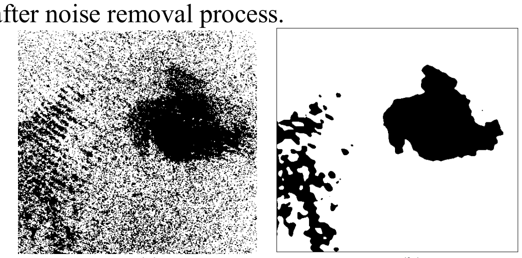
There is some limitation when we got our first grabbed image. First is the characteristic of the material, that is non-uniform texture of surface that makes the feature in image is covered with a lot of noise. Second one is the use of direct lighting that generates a noise in the center of specimen image. This noise have a circle form based on the shape of lighting system that is circle. Because of a lot of noise in the image we could not process directly. For preliminary process we adjust the contrast of the image to make the segmentation the defect is brighten from the whole image (Figure 2).



(a) (b)

Figure 2. Direct lighting noise removal: (a) Direct lighting noise. (b) Segmentation of the direct lighting noise.

Then, Gaussian filter is used to remove the noise, so that we can differentiate noise and defect in order to get the feature of defect. Figure 3 shows the defect feature before and after noise removal process.



(a) (b)

Figure 3. Filtering the noise and segmentation (a) non-uniform noise (b) Segmentation of defect from image

C. *Multilevel Thresholding*

After getting the feature of the defect by doing some simple segmentation method that we have done before, in this session we simplifying the defect into some gray-level region (some image editing application call it with gray-slice). After that contour level is used to indicate the roughness level on the defect of the surface. Figure 4 shows the feature of corrosion and scratch defect in 5-level contour.

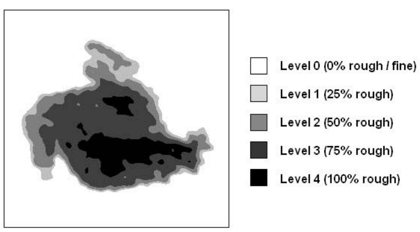
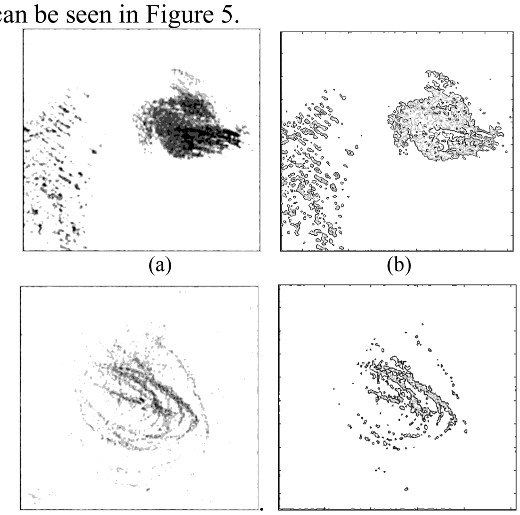


Figure 4. Feature of corrosion in 5-level contour

D. *Contour Dispersion*

From the multilevel thresholding image, we can simplify classify image with contour dispersion. This method divides the surface defect feature into some contour characteristic that can be seen in Figure 5.

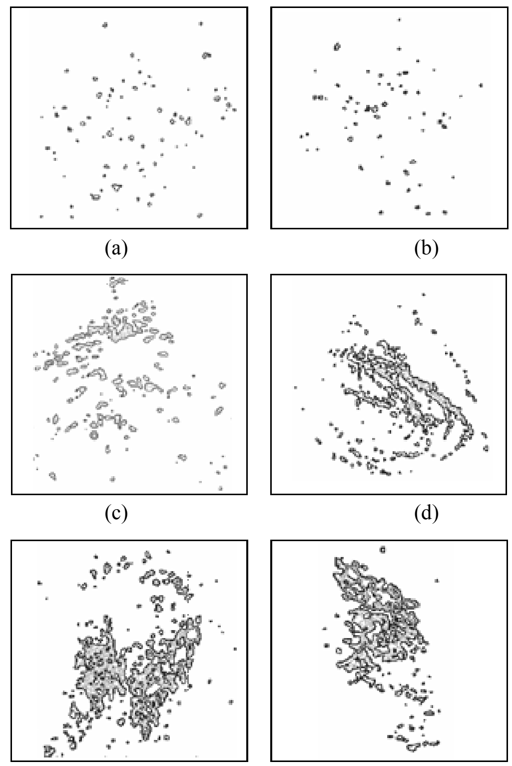


(a) (b) (c) (d)

Figure 5. Multilevel thresholding and contour process in defect: (a) Corrosion defect gray-level. (b) Corrosion defect contour. (c) Scratch defect gray-level. (d) Scratch defect contour.

IV. Result and Discussion

This experiment used three kinds of surface: 2 fine surface samples (Fine1 and Fine2) and 2 scratch surface samples (Scratch1 and Scratch2) and 2 corrosion surface samples (Corrosion1 and Corrosion2). Figure 6 shows a sample surface that has been characterized after contour process.



(a) (b) (c) (d) (e) (f)

Figure 6. Sample of surface defect characterization after contour process: (a) Fine1. (b) Fine2. (c) Scratch1. (d) Scratch2. (e) Corrosion1. (f) Corrosion2.

Picture (a) Fine1 and (b) Fine2 shows that the contour was spread in a few areas, and there is no significant high level defect. While picture (c) Scratch1 and (d) Scratch2 shows that the contour gather and spread around the scratch part, but the defect level is very low, almost same as the Fine1 and Fine2. The most significant high level defect is picture (e) Corrosion1 and (f) Corrosion2 that shows there are many regions of high level defects, usually placed in the center of contour. From this indication, we can specify and classify the defect in some level defect. For the classification, we divide the contour into five level defects: level 0 (0% rough), level 1 (25% rough), level 2 (50% rough), level 3 (75% rough) and level 4 (100% rough).

After classification, the final process is counting of the dispersion of defect level classification based on the contour of image. Table I shows the dispersion of defect level that presented in percent (%). Figure 7 shows the graph of the dispersion of fine level (level: 0), while Figure 8 shows the graph of the dispersion of defect level (level: 1, 2, 3, 4) which has been shows in Table I.

TABLE I. DISPERSION OF DEFECT LEVEL

Surface Sample	Defect Level (%)				
	0	*1*	*2*	*3*	*4*
Fine1	0.984	0.0054	0.0030	0.0046	0.0028
Fine2	0.982	0.0071	0.0033	0.0051	0.0022
Scratch1	0.964	0.0196	0.0089	0.0049	0.0030
Scratch2	0.963	0.0243	0.0085	0.0020	0.0019
Corrosion1	0.950	0.0204	0.0136	0.0073	0.0085
Corrosion2	0.935	0.0303	0.0161	0.0093	0.0089

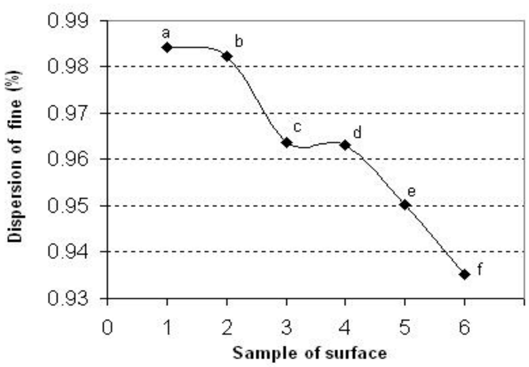


Figure 7. Dispersion of fine level: (a) Fine1. (b) Fine2. (c) Scratch1. (d) Scratch2. (e) Corrosion1. (f) Corrosion2.

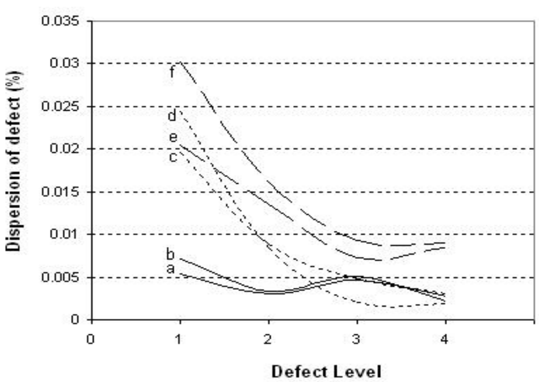


Figure 8. Dispersion of defect level: (a) Fine1. (b) Fine2. (c) Scratch1. (d) Scratch2. (e) Corrosion1. (f) Corrosion2.

In the dispersion of fine level graph, we can see that fine surface samples have same level around 98%-99%. Not too different with fine samples, while scratch surface samples is around 96%-98% in same level too. Corrosion surface samples are around 93%-95% in different variation in percent level. Contrary with dispersion of fine level, the dispersion of defect level graph, fine surface samples have a stable line distribution around 0.5%-1% for the low level defect and 0%-0.5% for the high level defect. While scratch surface samples have a decline line distribution around 2%-2.5% for the low level defect and 0%-0.5% for the high level defect. Corrosion surface samples have a decline line distribution around 2%-3% for the low level defect and 0.5%-1% for the high level defect. From this pattern, we can classify defect in order to get the feature and detail of defect especially scratch defect and corrosion defect.

V. CONCLUSION

This paper basically defines a surface defect characterization using contour dispersion. The basic idea of this research is to find an optimal multilevel threshold value for separating objects of interest in an image from the background based on their gray-level distribution using contour dispersion. In order to differentiate noise and defect, image contrast adjusting is used to brighten the segmentation of the defect from the whole image and Gaussian filter is used to remove the noise. The results show that contour dispersion can classify defect in order to get the feature and detail of defect especially scratch defect and corrosion defect and this method can provide accurately localized and closed region contours, which lays a good characteristic for defect feature extraction.

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