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Research paper

A Study on the Surface Image Processing of the Mixed Mineralized Lining

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Abstract

Background/Objectives: A method for qualitatively interpreting the special surface characteristics and the geometrical optics relationships, which are relatively important when intending to obtain the information of the objects from the contrast images, and for finally detecting the areas of the problems that look like the faults from the images (linings) of the solid bodies that are materialized with the mixed minerals is proposed.

Methods/Statistical analysis: By extracting the interested areas on real time by using the background differential images and by dividing the interested areas by carrying out a principal component analysis and by calculating the vector relations, whether or not there is a lining fault is decided.

Findings: This research proposes an image handling method that detects and classifies the problematic areas that look like the faults from the lining images which are materialized with the mixed minerals that were entered through the camera, and it shows the examples in which the method was actually applied.

Improvements/Applications: The method being proposed will be applied for automatically detecting the cracked parts on the surface of the lining, for classifying the types, and measuring the extent of the fault.

Keywords: *Geometric optics, lining surface inspection, computer vision, background differential image,Plane homography.*

1. Introduction

The visual system gets around to directly confronting the problem of inferring the geometric and physical properties of the environment which has been surrounding the observer or the surface of an object. The data that these visual systems can obtain are the intensities of the lights that were measured with a camera or a sensor. And these mainly appear in the secondary level images. The special features of the surfaces can be found from such secondary level images. As for the special, representative features, the distance between the observer and the surface of the object, the shape of the object, the direction, the designs, the reflection ratio of the surface, etc. can be mentioned[1-3].

This thesis proposes an algorithm which qualitatively interprets the special, surface characteristics and the geometrical optics relationships, which are relatively important when it is intended to obtain the information of an object from a contrast image and which finally detects the problem areas that look like the faults from the images of the solid bodies (the linings) that are materialized with the mixed minerals. Such an algorithm is an indispensable element in solving the problem of the recognition of the objects. A lot of the contributions for the actual applications at the industrial sites are highly expected, too.This research proposes a method for mechanically quantifying and detecting for the inspection of the faults of the surfaces of the linings, which had been relied on the previous, inaccurate, and inefficient, naked-eye inspections by the workers. And, through this, the more reliable production of the products becomes possible. The system that is developed through the algorithm that is being proposed can automatically detect and measure the diverse faults centered on the cracks of the surfaces of the automobile brake linings by using the computer vision technology[4-6]. By automatically detecting the damaged parts on the surfaces of the linings through this, the types of the cracks are classified and whether or not the product has a fault can be judged.

2. The Background of the Research

Among the processes for the production of the linings by the small- and medium-sized parts enterprises, the final inspection process has been entirely relying on the naked-eye inspections by the workers. The actual circumstance is that, because it is difficult for the workers to concentrate their attention for a long time, the not-so-small amount of the faults has been produced. The forms of the automobile brake linings are different according to the type of the car. For the smooth detection and analysis of the cracks, the type of the lining by the type of the car can be automatically extracted from the contour line information of the shape of the lining.

The method that is being proposed distinguishes the type of the lining by analyzing the image form of the lining. After dividing the input image according to the development of the real-time video division algorithm, the automatic extractor of the information of the type of the lining extracts the feature value. And, by matching with the model information that was obtained from the learning, the type of the lining gets decided[6].

Also, the lining surface inspection method that is being proposed in this research can effectively detect whether or not there is a crack or a damage to the lining surface, which takes place during the high-heat and high-pressure forming process of the mixtures of the brake linings. During this process, by using the special features of the surfaces that are regulated by the model of the lining, the linings that do not coincide with the special characteristics of the normal lining models are automatically sorted out. The cracks and the damaged parts of the lining surfaces get around to creating the shadows when the artificial illumination is shined on them. And these are detected by utilizing the computer vision technology. For the lining analysis, there is a need to design and produce a high-resolution CCD camera, a computer for the use with the analysis, an optical sensing device that controls the belt movements, the illumination, etc. The method that has been proposed gets used by being installed on the conveyor belt. In order to obtain an even more accurate image, the darkroom that has a CCD camera and the illumination is passed through, and, at this time, the lining image gets obtained and analyzed.Regarding the method that is proposed consequentially, a crack detection algorithm that will be applied to the application for classifying and measuring the types by automatically detecting the cracked parts on the lining surfaces was proposed and developed.

In Figure 1, the flowchart of the research method that was proposed is being shown.

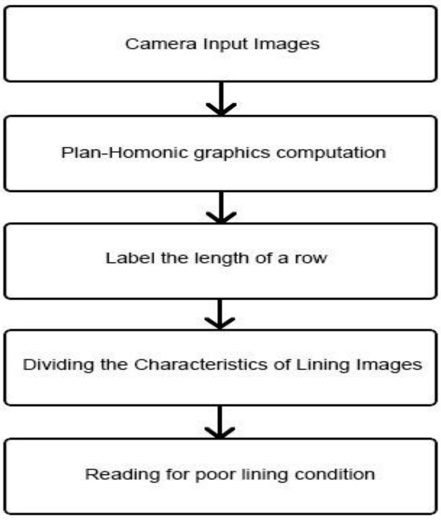

Figure 1:. The flowchart of the proposed research method

2.1. The Division of the Lining Image

In this thesis, the surface feature detection algorithm, which is efficient with the lining input images, is proposed. In order to extract the special feature points that are different from each other from an image sequence that is entered on real time through a camera, only the interested objects are detected through the background difference. The interested objects that are detected are classified by the run-length labeling. Also, by using the principal component analysis (PCA) algorithm regarding the object that was distinguished, the specific area is estimated, and the calculation takes place according to the time intervals[7]. When there is the object, the movement from the direction of the instruction by an instructor is distinguished by the condition of the movement and the stopped condition. When it is the stopped condition, the crack direction of the lining is distinguished.Regarding the organization of this thesis, in Chapter 3, the plane homography and the background differential method are described.In Chapter 4, the labeling algorithm is described. In Chapter 5, the results of an experiment according to the proposed method are shown. And, in Chapter 6, the conclusion is made.

3. The Process of the Pre-processing of an Image

When the brake lining image has been entered, carry out the image pre-processing process, which includes the process of the elimination of the noise (the noise reduction) of the image that can have the bad influences on the performance of the system and the process of the correction of the colors (the color correction). The pre-processing process is a series of the processing processes that transform into the forms with which the analysis of a surface image is easy. And carry out the process of the division (the segmentation) for carving in relief the feature part within the image. The image segmentation can be divided into the method of segmenting the area centered on the borderlines using the edge operator for extracting the borderlines of the objects within an image and the method of segmenting based on the area. As a result of experimenting with these two kinds of the methods, as a special characteristic of the lining image crack, it appeared that the case centered on the borderlines was more effective. The extraction of the borderlines of an image extracts the local discontinuity regarding the contrast of the image and the changes of the contrast. If this arithmetic operation is applied, the extent and the direction of the non-continuity of the distribution of the pixels can be obtained.

In this thesis, by considering the special, geometric characteristics of the images from the real-time image sequences and by applying the plane homography correction method, the feature points of each and every object are estimated[1].

All of the points that correspond in the two images can be expressed through the homography relationship. Or, in other words, between the corresponding points X' and x, which are on the plane regarding which the photograph was taken with one camera and the plan on which the illumination shines, there is the relationship that is the same as in Formula (1). The transformed H, which shows the relationship between them is called the "homography".

$$x' = Hx \tag{1}$$

$$H = \begin{bmatrix} \square_{11} & \square_{12} & \square_{13} \\ \square_{21} & \square_{22} & \square_{23} \\ \square_{31} & \square_{32} & \square_{33} \end{bmatrix}$$

If it is the interested plan Z = 0, which exists in the real world, it can be indicated as the point on this plane, which is x = (X Y 0 $1)^T$. And it can be expressed as x' = (x y $1)^T$, which is the point that was projected by the camera f. If it can be said that the camera projected line P is a line that projects the point in the 3-dimensional space as a point on the ground, the relation formula between the point that is on the plane in the real world and the camera-projected line is as in Formula (2).

$$x' = P_1 X = K[R|t](X\ \ Y\ \ 0\ \ 1)^r \tag{2}$$

$$= K[r_1 r_2 r_3\ t](X\ \ Y\ \ 0\ \ 1)^r$$

$$= K[r_1 r_2\ \ t](X\ \ Y\ \ 1)^r$$

$$= H^1(X\ \ Y\ \ 1)^r$$

Here, i3 is the camera-projected line of 3x4. And the table is the line of the parameters inside the camera of 3><3. And, among the external parameters of the camera, it pertains to the first and second rows and the movement vector of the rotation matrix.

3.1. The Arithmetic Background Differential Operation

As a method used for extracting the special features that are desired from an image sequence that was acquired through a fixed camera, it converts the background images and the present images that were acquired as the RGB color images into the grey-colored images. And it differentiates the grey areas (gray scales) of the input images (the input frames (IF's)) and the background images (the background frames (BF's)) into the pixel unit. The formula for calculating the front-view image (the foreground frame (FF)) by differentiating the background image and the input image is the Formula (3).

$$FF(x,y) = \begin{cases} 1, \text{if } |IF(x,y) - BF(x,y)| > Threshold \\ 0, \text{Otherwise} \end{cases} \quad (3)$$

In order to binarize (the binarization) the present area that was detected through the image differential and detect only the interested area, by carrying out the arithmetic operations of the erosion and the expansion (dilation), the pixels that get included in the object area and the pixels that do not get included in the object area are distinguished. This method is simpler and quicker than the other background differential method. And, in case it is used with a fixed camera, it is efficient.

3.2. The Run-Length Labeling

In this thesis, for the real-time handling, regarding the object that was extracted through the background differential, the special feature points are distinguished by applying the run-length labeling. Although the pre-existent Grassfire Labeling method does the search at one time from the starting pixels in one area to the end pixels in the area, as a method that engages in the search by one line at a time, the run-length labeling carries out the search of the next line after carrying a search of one line, and gives the consecutive numbers to each and every line in the area in which the object is distinguished. Regarding the area that was distinguished in this way, when there is an adjacent area through a comparison with the distinguished area of the upper line, it is finally distinguished as the same area. Not only can this algorithm be used with an area scan camera, of course, but, also, it can be used with a line scan camera, too. Because, in this case, the high-capacity data can be processed in the unit of the line on real time and because, at the moment when the scanning ends, not only the labeled image but, also, the extractions of the information regarding the objects end together, too, it is an effective image processing method through which the accurate results can be obtained. After dividing by centering on the cracked parts on the lining surfaces, if the borderlines that were obtained are processed by making them concise, the cracks on the lining surfaces can be expressed as the borderlines[8,9].

3.3. The Classification of the Types of the Linings

For the classification of the types of the linings, the contour lines information of the lining images are used in an important way. For the form analysis of a 2D image, the method in which the image division gets applied according to the permission that is centered on the area or the borderlines (edges) can become different. In the case of being centered on the borderlines (edges), the method through the detection of the curve point (corner) that becomes the special feature of the image and the method using the piecewise approximation have been known. The detection of a curve point explores the borderlines in the certain intervals, makes the chain codes, compares the direction values of the chain codes that were created, and is a method that re-codes the borderlines. By using the results of the re-coding, it can find the maxima and minima parts, which are the curve changes. And it is a method that finally calculates the desired inflection point based on this.

3.4. The Surface Cracks of the Linings

The lining surface cracks are analyzed through the process of the detection of the candidate crack area and the process of the extraction of the special, crack features after dividing the lining image. In the part of the detection of the cracked area, the contour lines of the linings are eliminated from the borderline image, and it possesses the function of preliminarily judging the borderlines inside the contour lines as the candidate cracks. And, in the part of the extraction of the special, crack features, by extracting the distance, the direction, etc. on the 2-dimensional plane between the candidate crack borderlines, they are made into the special features of the final crack judgments. For this, the Quad-Tree is used[10].

The Quad-Tree is an ordinary method that expresses the square images by hierarchically structuring them. Figure 2 has displayed the index structure drawing of the quaternary tree among the Quad-Tree methods.

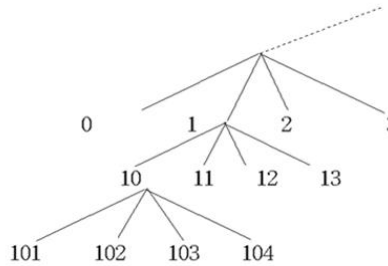

Figure 2. The index structure of the quaternary tree

4. The Results of the Experiment

Figure 3 consecutively shows the results of a feature division of a lining image.

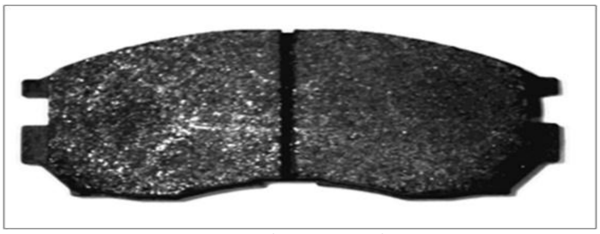

Figure 3(a).: The surface image of an input lining

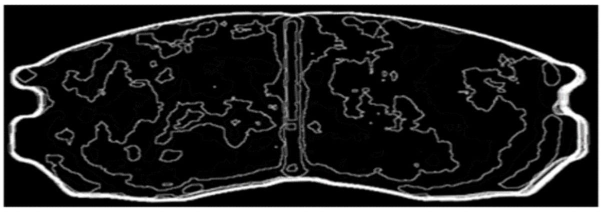

Figure 3(b).: The lining image feature division according to the area expansion

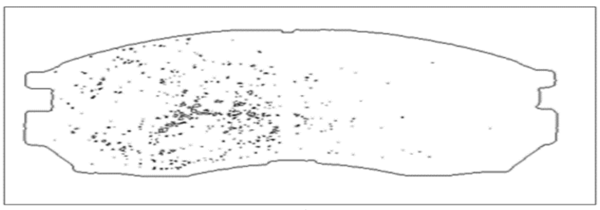

Figure 3(c).: The lining image feature division according to the borderlines (edges)

Figure 3.: The methods of segmenting the lining images

Figure 3 consecutively shows the results after feature-dividing a lining image. Figure 3(a) is an image of the input lining. And Figure 3(b) is the result after feature-dividing a lining image according to the expansion of the area. Figure 3(c) is the result after feature-dividing a lining image according to the borderlines (edges).

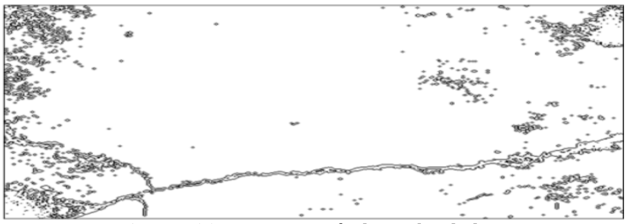

Figure 4(a).: An image of a lining borderline

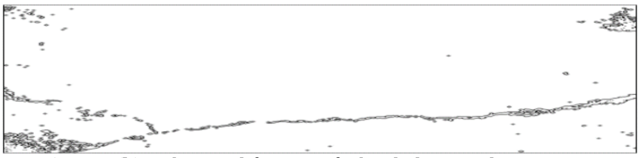

Figure 4(b):. The simplification of a borderline in a lining image

Figure 4(c). :An image of the elimination of the noise in a lining image

Figure 4.: An image of the pre-processing of a lining surface

Figure 4 consecutively shows the results after pre-processing from a camera-inputted image on the surface of a lining which is organized with a mixture.

Figure 4(a) is a borderline image that was obtained by processing a digital image. Figure 4(b) and Figure 4(c) show an image regarding which the simplification processing was carried out and an image of the result after eliminating the noise after dividing the borderline feature object which was obtained by applying the proposed algorithm.

5. The Learning of the Lining Analysis Information

Regarding the lining analysis, by analyzing the visual information of the lining that was inputted into a camera, it can receive the influences of the conditions of the illumination in the environment in which the analyzer is placed and the others of the like. And, by causing a change of the feature value resulting from this, it has an influence on the result. Hence, when there is a change of the environment of the analysis, the reliable results can be obtained only by adjusting this.

Regarding the hardware for the lining analysis, a high-resolution CCD camera, a computer for the analysis, etc. are needed.

The device for detecting the faulty linings which was proposed in this thesis gets installed on the conveyor belt. And, in order to obtain a more accurate image, the darkroom organized with a camera and the illumination is passed through. At this time, a lining surface image gets obtained and analyzed.

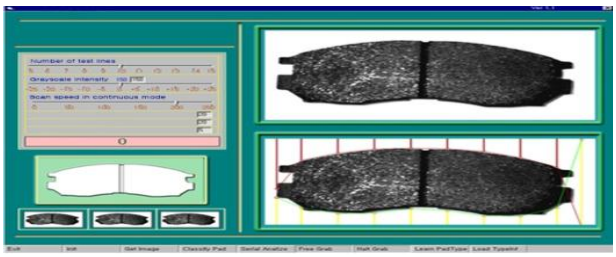

Figure 5:. A user screen for a lining analysis software

Figure 5 is a figure that shows the user screen of analysis software.

6. The Conclusion

The algorithm that is proposed in this thesis is a thing for the automation of the production process of the linings which are used as the important components of the automobiles. The algorithm for the classification of the types of the linings and which detects the crack flaws on the surfaces of the linings is proposed. Among the components of the automobiles, because, in the case of the linings, they go through the complicated process of mixing the diverse friction compounds and the high-pressure molding, the special characteristics of the surface brightness of the linings resulting from the process are very complicated. Because, in sorting out the faults of the linings and the others of the like at the site, the interpretation of the surface images of the linings is difficult, there are a lot of the difficulties in sorting out the products at the site. Regarding the method that was proposed, an algorithm to be applied to the system was developed in order to classify and inspect the linings that come carried on the conveyor belt on real time. I believe that, if the proposed system is applied to the field, the surface fault inspection can be automated, it will contribute greatly to the improvements of the productivity and the quality.

Acknowledgment

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