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A novel surface defect inspection algorithm for magnetic tile

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ABSTRACT

In this paper, we propose a defect extraction method for magnetic tile images based on the shearlet transform. The shearlet transform is a method of multi-scale geometric analysis. Compared with similar methods, the shearlet transform offers higher directional sensitivity and this is useful to accurately extract geometric characteristics from data. In general, a magnetic tile image captured by CCD camera mainly consists of target area, background. Our strategy for extracting the surface defects of magnetic tile comprises two steps: image preprocessing and defect extraction. Both steps are critical. After preprocessing the image, we extract the target area. Due to the low contrast in the magnetic tile image, we apply the discrete shearlet transform to enhance the contrast between the defect area and the normal area. Next, we apply a threshold method to generate a binary image. To validate our algorithm, we compare our experimental results with Otsu method, the curvelet transform and the nonsubsampled contourlet transform. Results show that our algorithm outperforms the other methods considered and can very effectively extract defects.

1. Introduction

Generally speaking, inspecting surface quality of magnetic tile before mounting is extremely significant. At present, inspection is accomplished by 'see and check' method in factory, which means that such process is performed by workers depending on their naked eyes. In this process, experienced workers evaluate the surface of magnetic tile carefully and judge whether a defect exists on the surface and what kind of defect it is, and it is very time-consuming. For the sake of this tedious and tiring job, workers always misclassify magnetic tile after working for a long time. Therefore, it is very crucial to develop an automatic system to correctly identify the surface defect.

In recent years, machine vision system has become the mainstream nondestructive strategy to solve this kind of problem, considering its characteristics of fast response and non-contact. The surface image of workpiece detected is commonly captured by CCD cameras with definite lighting condition [1]. Thus, many kinds of algorithms have been proposed to identify and classify the surface defect. Obviously, proposing an accurate and efficient algorithm is particularly pivotal for machine vision system.

In past decades, scholars around the world developed various algorithms applied to images based on machine vision. The algorithms commonly used can mainly be categorized as statistical, spatial domain analysis, morphological, frequency domain analysis, joint spatial domain and frequency domain analysis. Among these algorithms, spatial domain analysis, frequency domain analysis, joint spatial domain and frequency domain analysis are extensively applied to all kinds of surfaces.

Spatial domain analysis technology: Li et al. [2] presented an algorithm based on local annular contrast (LAC) for steel bar surface defects, such as pit, overfill and scratch. Yuan et al. [3] proposed an improved Otsu method using the weighted object variance for defect detection. Experiments showed that the improved Otsu method has a high detection rate and low false alarm rate for defect detection. Guo et al. [4] combined gradient operator with Fisher discriminant for image segmentation and this hybrid method could detect weak defection and real-time detect defection online.

Frequency domain analysis technology: Zhang et al. [5] adopted Gabor filter features and the statistical features to automatically classify the defects on the product surface in grinding and polishing. Yun et al. [6] also utilized Gabor filter feature to inspect thin and corner cracks in raw steel block by minimizing the cost function of energy separation criteria of defect and defect-free regions. Paulraj et al. [7] proposed to transform the image into frequency domain to compute the spectral energy as features by the Discrete Fourier Transformation (DFT) and the condition of

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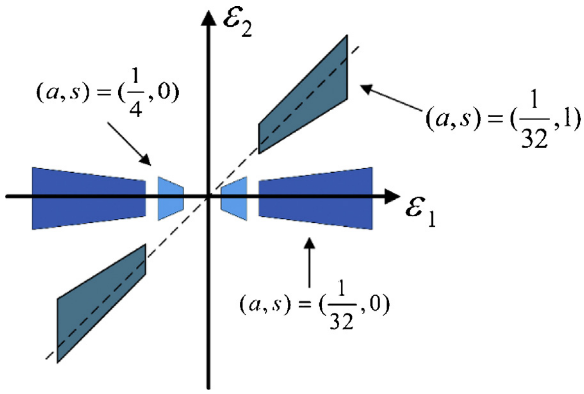

Fig. 1. Support of shearlets for different values of *a* and *s*.

structural steel could be recognized by Artificial Neural Networks (ANN).

Joint spatial domain and frequency domain analysis technology: Jeon et al. [8] proposed a vision-based method for detecting corner cracks on the surface of steel billets. Wavelet reconstruction is used to reduce the effect of scales. Texture and morphological features are used to identify the corner cracks among the defective candidates. Yun et al. [9] proposed two methods to improve the detection performance of scale-covered steel billet surfaces and these two methods could not only detect vertical line defects but also other defects. Yun et al. [10] presented the use of dynamic programming and a discrete wavelet transform for steel wire rods produced by the hot rolling process and used an adaptive local binarization method to further reduce the effects of scale.

Although the methods mentioned above all achieved high detection rates, they were very limited to some specific workpiece or defects. Because the contrast of magnetic tile image is relatively low and the background of image is rather complex, it is difficult to achieve a high detection rate using those methods. To understand the image features of defects more comprehensively and universally, it is a trend to use multi-scale signal analysis. Although wavelet and Gabor transforms, as traditional methods of multi-scale signal analysis, have been widely used in image processing area, they fail to decompose the image into different directions because of their limited directional sensitivity and isotropic support. Therefore, lying on the foundation of Olshausen and Field's work [11], researchers proposed more advanced technologies to process original image, which could decompose the image into different scales and directions and extract more information in detail. These advanced technologies are called multi-scale geometric analysis (MGA) or beyond wavelets [12]. Currently, the methods of MGA mainly include the curvelet transform [13,14], the contourlet transform [15,16], the bandelet transform [17,18] and the shearlet transform [19,20], etc. Among these methods, Li et al. [21] proposed to adopt the fast discrete curvelet transform to decompose the original image and use texture analysis to determine the proper threshold to reconstruct image. Although this method achieved a high detection rate for magnetic tile, it only could be applied to detect surface cracks. The contourlet transform inherits the anisotropic characteristics of the curvelet transform, which is a combination of a multi-scale and a directional filter bank, but the directional features are less clear than the curvelet transform. However, the curvelet transform and the contourlet transform cannot directly process images without information of edges and contour of image. Compared with the curvelet transform and the contourlet transform, the bandelet transform is an adaptive method of MGA, possessing the advantages of both the curvelet transform and the contourlet transform. But it is complicated to search the best bandelet basis. The shearlet transform, as a relatively new method of MGA, is optimal in approximating 2D smooth functions with discontinuities along C2-curves, compared with other methods of MGA. Thus, it is superior to other methods of MGA in processing images with low contrast and complex background. Xu et al. [1] successfully applied the shearlet transform to classification of surface defects for metals and its accuracy was higher than 92.5%.

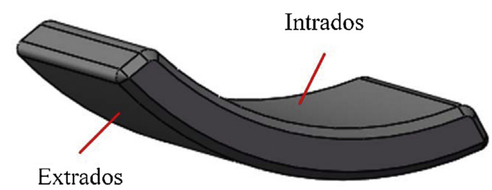

Fig. 3. The 3D model of magnetic tile.

In this paper, we propose an image enhancement algorithm for magnetic tile surface defect detection based on the shearlet transform. The remaining parts of this paper are organized as follows. The theory and properties of the shearlet transform are briefly recalled in Section 2. In Section 3, we analyze the characteristics of magnetic tile image and the design of our proposed method can be found. In Section 4, experimental results and discussion are presented. Conclusion is described in Section 5.

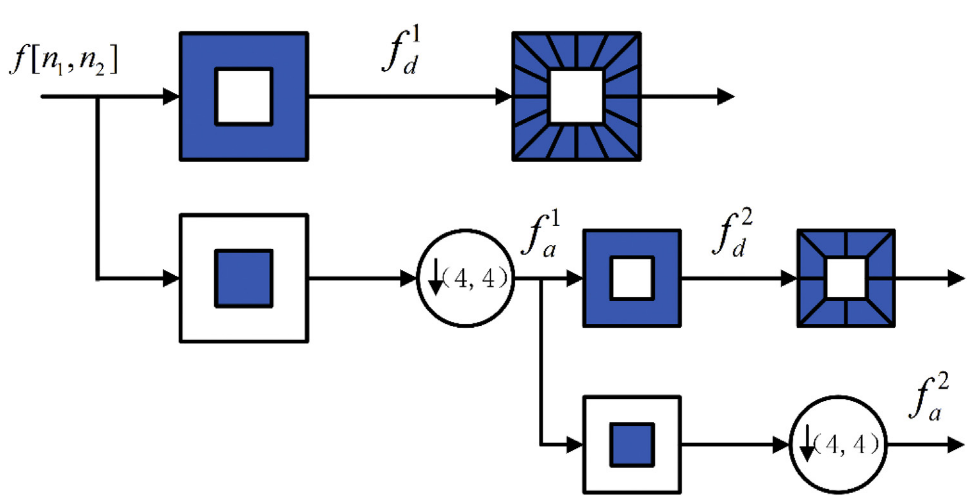

Fig. 2. The schematic of theshearlet transform.