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A novel algorithm for defect inspection of touch panels☆

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ABSTRACT

Automatic optical inspection plays an important role to control the appearance quality of wide range of products in the product process. Recently, the high popularity of smartphones and information appliances drives significant demand of touch panels. However, the traditional frequency-based method which exploits the line structure feature of texture images is not effective for the defect detection of touch panels. The paper presents a novel spatial domain algorithm to inspect the defects on touch panel. By utilizing the characteristics of periodic patterns of the sensing circuits, an adaptive model for each pattern is learned online to effectively extract defects. The experimental results indicate that our proposed method achieves accurate detection with efficient computation. In addition, the users pay very little effort for the testing of different panel products.

1. Introduction

Surface inspection based on machine vision has been widely used for quality control in manufacturing various products. A large variety of surfaces such as wood, steel, wafer, ceramics, fabric, fruits and aircraft surfaces have been studied [1] in the past two decades. However, few researches on touch panels have been reported [2,3]. A touch panel is a piece of equipment that lets users interact with computing devices such as smartphones, personal computers, cashier machines, and ATM. Recently, the high popularity of smartphones, pads, and many types of information appliances is driving the great demand of touch panels. The appearance quality of touch panels affects their yield rates significantly in manufacturing process. In [18], the authors listed the defect rates of 12 inspection workstations in the production process for a touch panel manufacturer. Total defect rate is 36.2%. There are four workstations related to sensing circuits, included touch panel clean, protect film attachment, pre-test of sensing circuit and function film attachment. The total defect rate of the four stages is 14.1%, which is approximately to 39% of the defect rate of the whole process. Therefore, automatic optical inspection (AOI) for the surface defect of the sensing circuits of the touch panel is urgently required in the production process.

Sensing circuits are always coated in the touch panels in a regular arrangement, as illustrated in Fig. 1(a). In the real case, the defects such as particles, scratches, fibers and strains, are often embedded into sensing circuits as shown in Fig. 1(b), so the inspection task becomes how to extract defects from circuit patterns. However, every panel product has its particular sensing circuit structure, which means a large variety of circuit patterns exist. This makes developing a universal inspection algorithm for different products very challengeable.

Many existing defect detection systems focused on non-textured surfaces such as glass panel, sheet steel, aluminum strips and web materials. The images of this type of surfaces have uniform gray-level, thus simple thresholding or edge detection techniques in spatial domain [4,5] are often used to detect defects. These kinds of defects can be easily detected because commonly used measures usually have very distinct values [4]. As for texture surfaces, defect detection is to compute a set of textural features, and search for significant local deviations in the feature values. The selection of an adequate feature set is critical but difficult. Moreover, a set of features which is optimal in the representation of a specific texture could be completely useless for other texture patterns [4]. For texture-based defect detection, the approaches can be roughly classified into four categories: statistical, structural, filter based and model based [1,6]. The filter-based approach is most popular, which includes spatial domain filtering, frequency domain analysis and joint spatial/spatial-frequency approaches. The three techniques used in frequency and spatial/frequency domain analysis are: Fourier transform [4,7,8], wavelet transform [9–12] and Gabor filter [13–14].

For touch panel inspection, the works presented in the literature still treat the sensing circuits as texture patterns, and apply frequency-based filtering methods to extract defects [2,3]. The common point of these methods is to design a filtering mask in frequency domain to remove background patterns such as circuit parts, and only defects appear in the reconstructed image. In [3], the authors analyzed some touch panels with directional line structures and found that the high-energy distributed along four directional lines, i.e., horizontal and vertical lines, and two diagonal lines flipped horizontally each other. Thus, they design

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0262-8856/

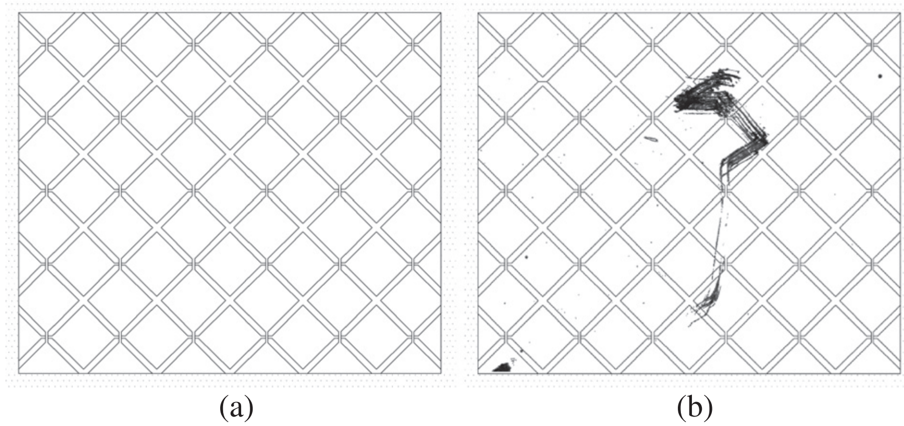

Fig. 1. (a) An example of touch panel image, (b) defects embedded into sensing circuits.

four notch filters using the scheme similar to [4] to successfully remove the circuit parts and detect the defects.

To investigate the effectiveness of the frequency domain filtering methods, we apply the method presented in [3,4] to two defect-free touch panels, Product I and Product II, and the results are demonstrated in Fig. 2. Fig. 2(a)–(b) shows two sensing circuit images from two panels. By performing fast Fourier transform (FFT) to the images, we obtain the energy spectrums shown in Fig. 2(c)–(d). Generally, the major energy seemly distributes along four directional lines, i.e., horizontal, vertical, and two diagonal lines, as pointed out in [3,4]. However, detailed observations indicate that the distributions of energy spectrum are quite complex and not so regular. The high energy not only occurs at the neighborhood of the four directional lines, but also appears at other frequency components. In addition, the shape of the distribution varies with different products. For example, Product I exhibits shape like a bug (see Fig. 2(c)), and the shape of Product II exhibits like a snow flower (see Fig. 2(d)).

The angles of the diagonal lines change with different structures of sensing circuits. The angle of the diagonal line can be estimated by the maximum of the directional projection on the spectrum image. Fig. 2(e)–(f) shows the estimated angles of the diagonal lines are respectively 25° and 31° for Product I and Product II. Based on the estimated angles, we design four line-shape notch filters with appropriate bandwidths by the method in [3]. By applying the notch filters to the spectrum images, and then performing the inverse FFT, we obtain the reconstructed images, as shown in Fig. 2(g)–(h). Observing the reconstructed images, it is seen that some circuit parts are not completely removed, and some flat parts (non-circuit parts) are changed a lot, especially for Product II.

The above analysis indicates that the complicated shapes of energy spectrum make the design of effective notch filters rather difficult. Thus, the frequency domain filtering method is very useful for the textures with pure line structures. However, we argue that it is not effective for the defect detection of general touch panels.

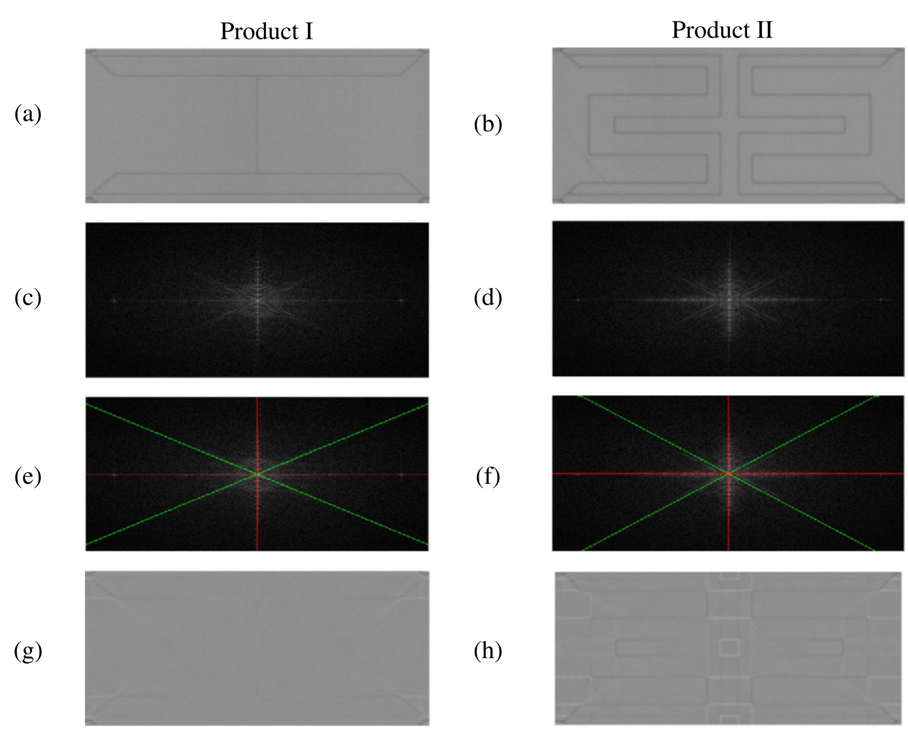

Fig. 2. (a)–(b) Sensing circuit images, (c)–(d) Fourier spectrum images, (e)–(f) four principal bands, (g)–(h) reconstructed images after filtering.