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An innovative blemish detection system for curved LED lenses

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ABSTRACT

The functions of LED lenses include focusing, beauty, and protection to avoid the waste of light and light pollution. Nevertheless, LED lens with a transparent and curved surface is more difficult to detect the visual blemishes than electronic and optical components by current computer vision systems. This research proposes an innovative blemish detection system to detect visual blemishes of the curved LED lenses. A spatial domain image with equal sized blocks is converted to discrete cosine transform (DCT) domain and some representative energy features of each DCT block are extracted. These energy features of each block are integrated by the Hotelling's T-squared statistic and the suspected blemish blocks can be determined by the multivariate statistical method. Then, the grey clustering technique based on the block grey relational grades is applied to further confirm the block locations of real blemishes. Finally, a simple thresholding method is applied to set a threshold for distinguishing between defective areas and uniform regions. Experimental results show that the proposed system achieves a high 95.46% probability of correctly discriminating visual blemishes from normal regions and a low 0.13% probability of erroneously detecting normal regions as blemishes on curved surfaces of LED lenses.

1. Introduction

A lens is an optical device with perfect or approximate axial symmetry which transmits and refracts light, converging or diverging the beam. Lenses are typically made of glass or transparent plastic. Optical lenses are transparent components made from optical-quality materials and curved to converge or diverge transmitted rays from an object. These rays then form a real or virtual image of the object. There are many types of optical lenses. Optical lenses are widely used in cell phones, notebooks, automotive lights, digital cameras, scanners, head lamps etc.

A light-emitting diode (LED) is a semiconductor device that emits visible light when an electric current passes through the semiconductor chip. Compared with incandescent and fluorescent illuminating devices, LEDs have lower power requirement, higher efficiency, and longer lifetime. Typical applications of LED components include indicator lights, LCD panel backlighting, fiber optic data transmission, etc. To meet consumer and industry needs, LED products are being made in smaller sizes, which increase difficulties of product inspection. The functions of LED lenses include focusing, beauty, and protection to avoid the waste of light and light pollution. An LED without the assistance of lens focus function cannot project light to the intended location. Therefore, LED lenses are invented to improve the light scattering problems of LEDs and they are widely applied to hand flashlights and traffic lights applications. Fig. 1 shows the common LED lens and LED lens product.

Lens inspection requires special physical conditions, particularly in terms of lighting. In the real working situation, each inspected lens is brought into the inspector's field of vision. The lenses are round and transparent; the blemish to be inspected could be located on the external surface of the lenses or inside. A lens presents a certain thickness and a certain curvature, both of which vary. At times, lenses provide the same perceptive result as a magnifying glass, and the blemishes are all the more difficult to track down and to locate in the area of the lens. The majority of blemishes are not only very small but also they are extremely diverse and can assume various forms. Fig. 2 presents LED lenses with and without visual blemishes.

Currently, the most common detection methods for LED lens blemishes are human visual inspection. Human visual inspection is tedious, time-consuming and highly dependent on the inspectors' experiences, conditions, or moods. Erroneous judgments are easily made because of inspectors' subjectivity and eye fatigues. Difficulties exist in precisely inspecting tiny flaws by machine vision systems because when product images are being captured, the area of a tiny flaw could expand, shrink or even disappear due to uneven illumination of the environment, transparent and curved surfaces of the product, and so on. Seeing the great need for an automated visual detection scheme for LED lens blemishes, we propose an innovative detection system applying block discrete cosine transform (BDCT) and gray clustering technique to overcome the difficulties of traditional machine vision systems.

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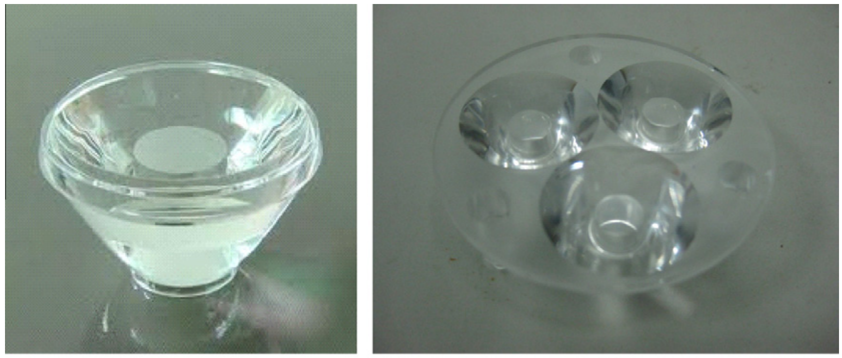

Fig. 1. (a) An LED lens (side view); (b) an LED lens product (top view).

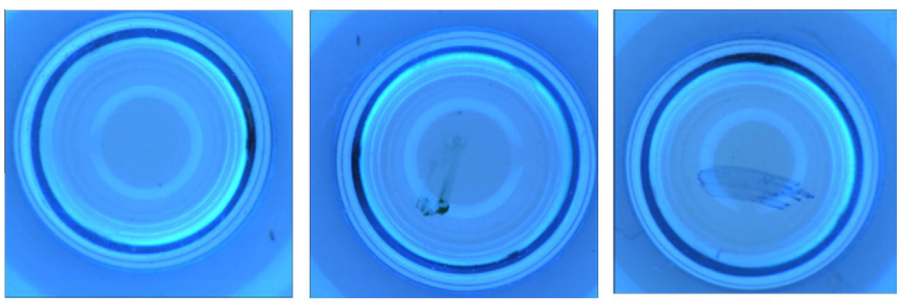

Fig. 2. LED lenses with and without visual blemishes (from top view) (a) LED lens without blemish; (b) LED lens with dirt blemishes; (c) LED lens with scratch blemishes.

2. Blemish inspection methods

Inspection of surface blemishes has become a critical task for manufacturers who strive to improve product quality and production efficiency (Lin & Lin, 2009; Lin, Lin, Chung, & Lin, 2008). Blemish detection techniques, generally classified into the spatial domain and the frequency domain, compute a set of textural features in a sliding window and search for significant local deviations among the feature values. Latif-Amet, Ertüzün, and Ercil (2000) presented wavelet theory and co-occurrence matrices for detection of blemishes encountered in textile images and classify each sub-window as defective or non-defective with a Mahalanobis distance. Cho, Chung, and Park (2005) applied the adaptive threshold technique and morphology method to detect defects from images of uniform fabrics for developing a real-time vision system.

As to techniques in the frequency domain, Chan and Pang (2000) used the Fourier transform to detect fabric defects. Tsai and Hsiao (2001) proposed a wavelet transform based approach for inspecting local defects embedded in homogeneous textured surfaces. By properly selecting the smooth sub-image or the combination of detail sub-images in different decomposition levels for backward wavelet transform, regular, repetitive texture patterns can be removed and only local anomalies are enhanced in the reconstructed image. Also, Lin and Ho (2007) developed a novel approach that applies discrete cosine transform based enhancement for the detection of pinhole defects on passive component chips.

As to inspecting blemishes of lenses, Rebsamen, Boucheix, and Fayol (2010) described quality control tasks in the optical industry from a work analysis of optical lens inspection to a training program. Martínez, Ortega, García, and García (2009) developed a vision sensor planning system for automated inspection of headlamp lenses. This system uses the lens CAD, a vision sensor model and the customer requirements describing by a fuzzy approach, to achieve an optimal set of viewpoints by genetic algorithm. Bazin, Cole, Kett, and Nixon (2006) proposed a novel method for the industrial inspection of ophthalmic contact lenses in a time constrained production line environment. Perng, Wang, and Chen (2010) presented a new inspection system that uses machine vision to detect optical blemishes in quasi-contact lenses. The optical region of the lens image is first segmented, then the middle axes of each fringe on the optical region are determined. Three features of the fringe are extracted to create a mapping of the original features to a semantic description of the textures. Finally, the quality of the quasi-contact lens is determined by a control chart procedure. Therefore, most of the existing researches focus on inspections of optical lenses, headlamp lenses, and contact lenses. They do not detect blemishes with the properties of tiny blemishes on LED lenses. Consequently, we present a new approach using block discrete cosine transform and grey clustering for blemish detection of the transparent and curved LED lens surfaces.

Ahmed, Natarajan, and Rao (1974) first defined DCT as one-dimensional (1-D) and suitable for 1-D digital signal processing. Most of the researchers that apply DCT for image processing focused on image compression and image reconstruction, because DCT has the property of packing the most information into the fewest coefficients (Gonzalez & Woods, 2008). However, due to the lack of an efficient algorithm, DCT had not been applied as widely as its properties imply. Only until recently, many algorithms and VLSI architectures for the fast computation of DCT have been proposed (Kok, 1997). To enhance edges of remote sensing image data in the DCT domain, Chen, Latifi, and Kanai (1999) developed new and fast algorithms that involve three steps: high-pass filtering, gray levels adding, and contrast stretching.