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Theory research of glare reduction based on the Fresnel principle☆

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ABSTRACT

Glare reduction is the focus of much attention in the field of optical engineering owing to its vital role in high-quality image acquisition in photoelectric visual inspection technology. Based on Fresnel reflection theory, we have derived a polarization factor related to the glare intensity distribution and have obtained theoretical results showing that the factor plays a leading role in reducing glare. Based on the image detection model, we have derived a displacement factor which determines the position and the size of the glare area, and have obtained theoretical results showing that the factor plays a supporting role in reducing glare. The image gray-scale transformation curve is obtained by sampling image data under the different polarization and positions. And these image data are measured from certain object in the equivalent environment while the different conditions. Then the theories above have been justified and the whole theory of the polarization-based glare elimination method has been interpreted completely via actual experiments in glare elimination. As a result, reducing the intensity contrast between the glare area and its neighboring area is proved to be the essence of glare elimination. Furthermore, the glare can be nearly eliminated perfectly by adjusting the polarization factor and the displacement factor.

1. Introduction

The global technology revolution represented by INDUSTRIE 4.0 requires higher-performance photoelectric visual inspection methods. Industrial automation has accessed robotic generation and photoelectric visual inspection technology and these has been applied in some fields, such as on-line product inspection, manufacturing process monitoring, high-precision measurement, automatic recognition and location, *etc*. However, in such types of application, the surface of most of the measured object reflects glare owing to the position, the angle and the complexity of the intensity distribution of the light source, which would cause the incorrect segmentation of the region of interest (ROI) region in image pre-processing, thus lowering the accuracy of inspection in visual inspection systems [1,2]. To reduce, or eliminate, the interference from the glare and stray light, respectively, usually the polarizer and the analyzer would be placed in front of the light source and the aperture [4,5], as shown in Fig. 1.

The polarization-based glare elimination model originated from the use of the analyzer as applied in front of the lens [5]. In its subsequent development, it was found that adding the polarizer in front of the light source could not only improve

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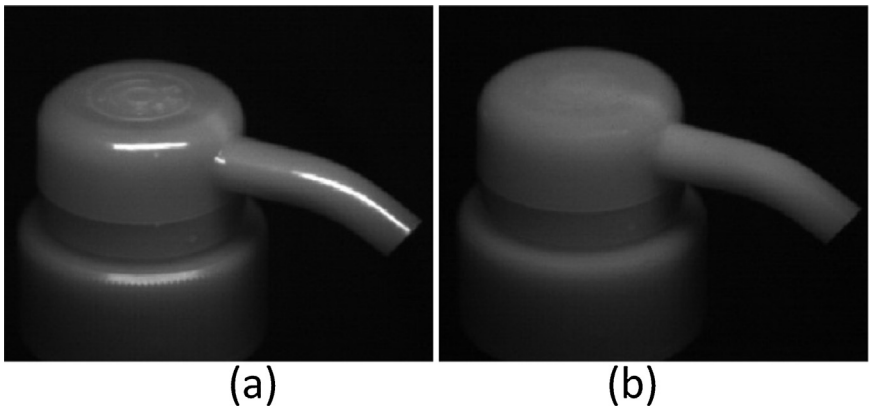

Fig. 1. The contrast with the before and after eliminating glare: (a) Glare and (b)Glare-free.

the image quality but also improve the performance of glare elimination [6]. The aforementioned method was then widely applied in industry and a large number of articles about the application of the polarization-based glare elimination model have been published. Shen S et al. [7] obtained a relative precision velocity value via the measurement of the droplets sizes of a flash boiling spray using the scatterting effect of glare point, Tsai M S et al. [8] designed a high-performance LED luminaire for lowing the glare reflecting into the human eyes, Salakhutdinov V K et al. [9] designed a glare-free optical lens for fundus visualization, Chen P L et al. [10] designed a portable inspection system that can optimize the visual experience by estimating direct glare of various LED modules, but there have been no articles that could fully interpret the theory of this glare elimination method.

This work interprets the theory of glare elimination based on Fresnel reflection theory. First, we derived the polarization factor that effects the distribution of glare intensity based on the basic imaging model. Then we defined the relative positions of the light source, object, and image sensor as a displacement factor. In the end, compared with the experimental results, the theory of glare elimination was verified successfully, and the conclusion was reached that, reducing the intensity contrast between the glare area and its neighboring area was the essence of glare elimination. The glare could be almost eliminated perfectly by using the polarization factor and the displacement factor.

2. Polarization factor

The basic visual imaging model integrated with traditional BRDF theory [11–13] is shown in Fig. 2(A). To obtain the intensity distribution on the image sensor, a single point imaging model, shown in Fig. 2(B), is built based on the scalar equation

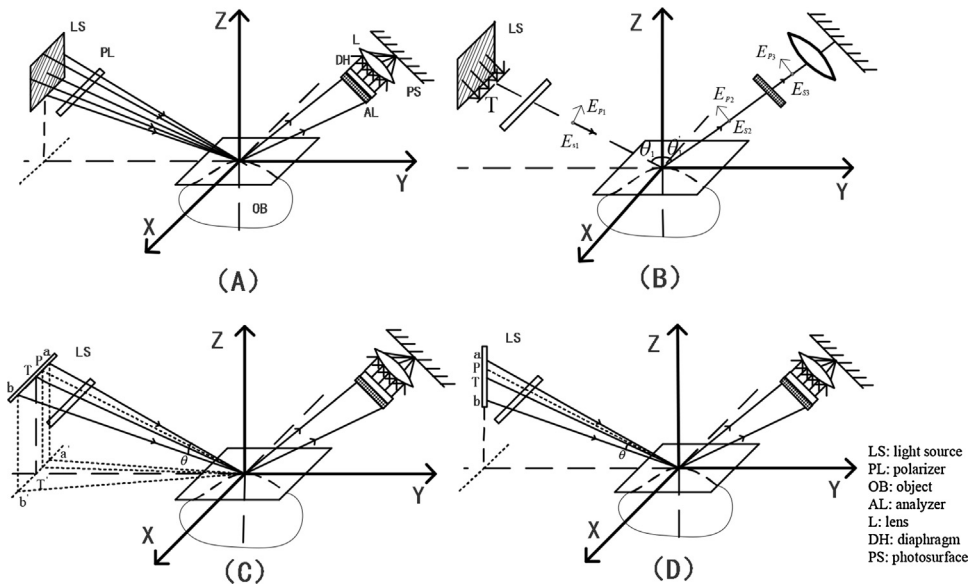

Fig. 2. Diagram for theoretical analysis: (A) Basic visual imaging model; (B) Single point imaging model; (C) p-polarized(parallel); (D) s-polarized(perpendicular).