Optics and Laser Technology 106 (2018) 481–486

Contents lists available at ScienceDirect

Optics and Laser Technology

journal homepage: www.elsevier.com/locate/optlastec

Full length article

# An optimizing iterative approach with objective sharpness evaluation in adaptive projection system

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ARTICLE INFO

*Article history:*
Received 29 November 2017
Received in revised form 16 March 2018
Accepted 25 April 2018

*Keywords:*
Adaptive illumination
Exposure compensation
Iteration
Sharpness evaluation

ABSTRACT

In order to modify the local luminance heterogeneity of target object image, restrain the phenomenon of overexposure and preserve enough original image information, we analyzed the adaptability of the adjustable projection which is applied to exposure compensation. In this paper, a novel iterative method by using the improved algorithm for absolute center moment (IACM) is proposed. A projector-camera system with the iterative algorithm is built to adjust the adaptive projection according to the inversion theory, the differences of depth information and the illumination intensity. Among them, the role of depth information is correspond to different light intensity at different heights. Through the experiment, the result shows that the camera could achieve uniform luminance and the index convergence is evaluated by IACM. This system can output the image with better definition based on iterative stop criterion, thereby the number of iterations is limited and objectively countable. This technique is suitable for industrial measurement, defect detection and quality control in real-time measurement.



## 1. Introduction

The visual quality of the most recorded images is inevitably degraded in industrial applications because of ambient light, uneven target surfaces and inhomogeneous reflection-absorption properties of the target or both [1]. Generally, these methods can be categorized into image enhancement, feature extraction on image-processing algorithms, hardware upgrades for cameras and illumination control [2–7]. Among them, illumination control plays a crucial role because better result will be acquired if better raw image information is measured. Many studies have made great contributions to illumination control. For example, Hassan et al. enhanced super resolution to equalize the luminance distortion [8]; Conde et al. used different LEDs with different wavelengths to obtain accurate information [9]; and some people set specific CCD cameras placement angle and specific light source to measure surface gloss and defect inspection [10,11]. Most of these methods have complex structures.

In addition, the approach of controlling projection was proposed by some papers based on projector-camera system. In Castellini's study [12], the projected spatial distribution of light was determined by implementing an image inversion algorithm; one year later, they proposed a new algorithm through genetic algorithms [1]. Although these methods made the results convergence, they were not complete without the suitable stop condition and also did not point out how many iterations a good image needs. In our previous studies [13], depth information was introduced to provide different illumination for different depths; however, no reasonable evaluation system was introduced, only by artificial discrimination.

In this paper, we propose a new approach for adaptive illumination to control projection in the 3D scene, the main purpose of this approach is to use modified iterative algorithm with a complete image sharpness evaluation system. This new approach can automatically output the image with better definition after limited iterations. In projector-camera system, the iterative algorithm, which includes inversion theory, depth information and the illumination intensity difference, computes the result image achieved by the CCD camera firstly; then the projector projects the calculated result to the target object. The depth information is the key to the adjustable projection and is corresponding to the illumination intensity of the target object. We use random two-step phase-shifting profilometry [14] to eliminate aliasing and this method has good randomness and accuracy. In addition, a reasonable sharpness evaluation algorithm is introduced to evaluate the image objectively by the improved algorithm for absolute center moment (IACM). In summary, the experiments have proven that the IACM index of adaptive projection result is convergent and the iterative stop criterion limits the number of iterations to get the optimized image without overexposure.

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https://doi.org/10.1016/j.optlastec.2018.04.035

## 2. Principle

As shown in Fig. 1, the traditional illumination and the adjustable illumination are compared and the main difference is the projection light. In the traditional illumination shown in Fig. 1(a), a uniform light distribution is projected from a given direction over the surface, but most of the objects in our experiment exist not only in diffuse reflection but also in specular reflection. For CCD camera, its exposure values have two key parameters to control the dynamic range: the minimum exposure value $C_l$ of the signal-to-noise ratio within acceptable range and maximum exposure value $C_h$ which enters the state of overexposure. The camera exposure which is less than $C_l$ makes the signal-to-noise ratio decrease and random noise increase; more than $C_h$ leads to excessive saturation of the image. As a result, the bright region becomes white, and the useful information loss of the image is serious.

However, in the adjustable illumination shown in Fig. 1(b), projection light is non-uniform light in which the low-reflective region increases exposure and the high-reflective region decreases exposure to get a better illumination. For example, the white triangles in the measured image shown in Fig. 1(a) is unsharp, while in Fig. 1(b) the integrity of information is visualized.

In order to obtain the adjustable illumination, we introduce an iterative algorithm based on adjustable projection.

Firstly, acquire the target object's image $L_1(x, y)$ with projection light and background light by CCD camera. The sum of the projection light intensity and the background light intensity is $I_1(x, y)$. In order to accelerate iteration speed, we use the inverse calculation to get the first iterative image $I_2(x, y)$, as

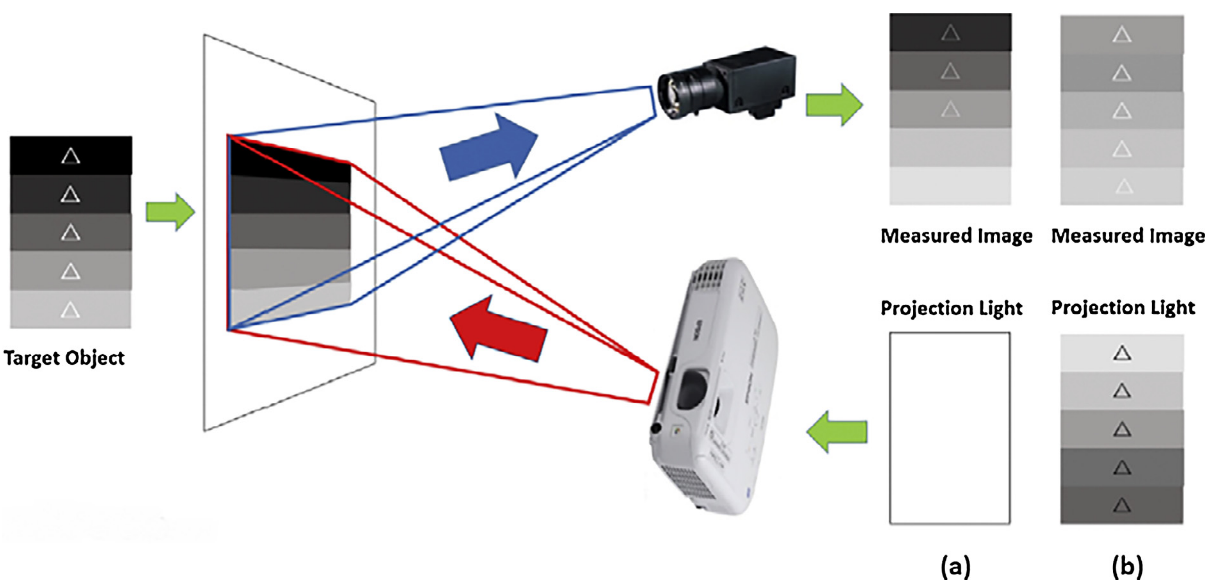


**Fig. 1.** (a) The traditional illumination, (b) the adjustable illumination.

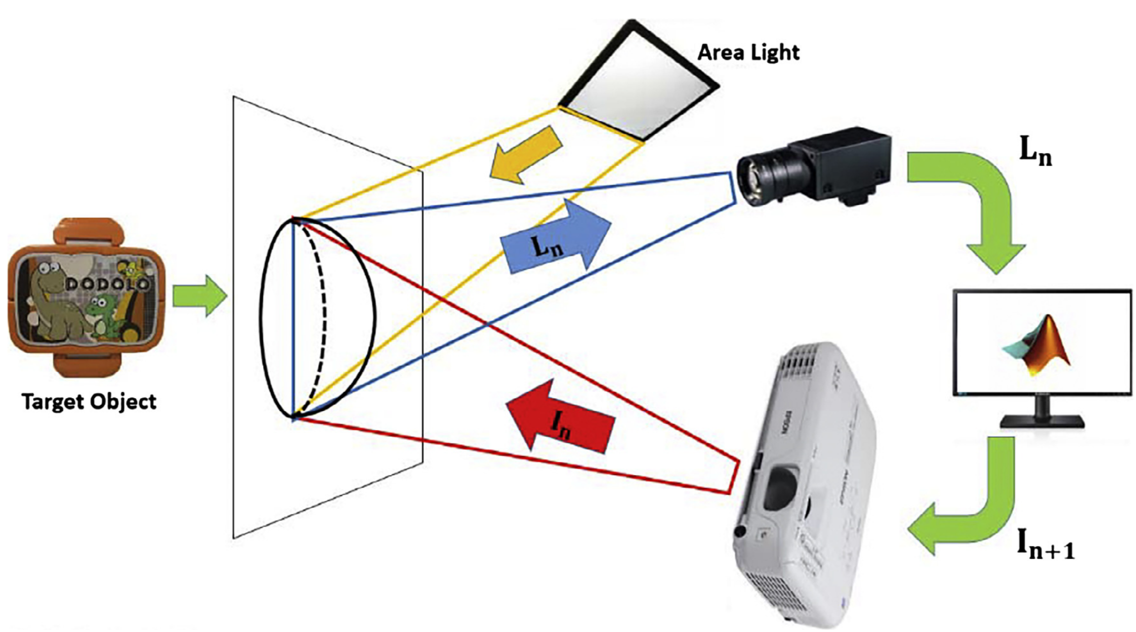


**Fig. 2.** Diagram of iterative algorithm.