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RECOGNITION OF A SCATTERING 3D OBJECT USING AXIALLY DISTRIBUTED IMAGE SENSING TECHNIQUE

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ABSTRACT

In this paper, we present a recognition method for a 3D object in scattering media by using the axially distributed sensing (ADS) method and nonlinear correlation operation. Since the scatter noise for a 3D object is recorded into the elemental images by ADS method, we apply a statistical image-processing algorithm to convert the scattering elemental images into the scatter-reduced ones. After obtaining the scatter-reduced elemental images, the 3D plane images are reconstructed using the computational reconstruction algorithm based on ray back-projection. The reconstructed plane images are used for 3D object recognition in the scatter medium. We perform the optical experiments and present the experimental results.

Keywords: axially distributed image sensing; three-dimensional visualization; scatting medium.

INTRODUCTION

Visualization and recognition of 3D object in optically scattering media is a challenging problem. An improved visualization method of scattered images can be applied to various applications such as imaging in fog, underwater, security, and medical diagnostics [1-6]. Some 3D multi-perspective approaches including integral imaging and axially distributed sensing (ADS) have been studied for visualizing objects in the scattering medium [6-8]. In 2008, Moon and Javidi firstly proposed a visualization method of 3D object in a scattering medium using integral imaging. Here, the computational geometrical ray propagation algorithm is applied to the scattered elemental images to eliminate the interference patterns between scattered and object beams [6]. In 2010, Cho and Jaivid studied an improved method for visualization of 3D objects in a scattering medium. Here, a statistical image processes and computational integral imaging reconstruction algorithms were used to remedy the effects of scattering [7]. Until now, the previous methods have been focused on the visualization of scattered 3D objects. It is hard to find a report about the recognition of 3D objects in the scattering medium

In this paper, we present a recognition method for a 3D object in scattering media by using the axially distributed sensing (ADS) method [9-11]. The proposed method is divided into four parts: (1) pickup (2) statistical image processing (c) computational re-construction and (d) recognition. To show the feasibility of the proposed method, we carry out the optical experiments.

This paper is organized as following. We briefly introduce the ADS method. A description of computational reconstruction using statistical image processing techniques and a recognition algorithm are presented. Finally, the experimental results are presented for objects in the scattering medium.

RECONITION METHOD USING ADS

Pickup method in ADS

The pickup part of the ADS method is shown in Figure-1. We translate a single camera along the optical axis and record multiple 2D images of the scene observed through the scattering medium. We suppose that the object is located at a distance z_0 from the 1st camera position. The distance between the cameras is Δz. We record K elemental images by moving the camera. The first camera is k=1 at z_k=z_0 and the camera closest to the object becomes by k=K at z_k=z_0-(K-1) Δz. Due to the different distance from the object for each camera, the object is recorded in each elemental image with a different magnification. Each magnification ratio is calculated as M_k=z_k /g where g is the focal length of the camera.

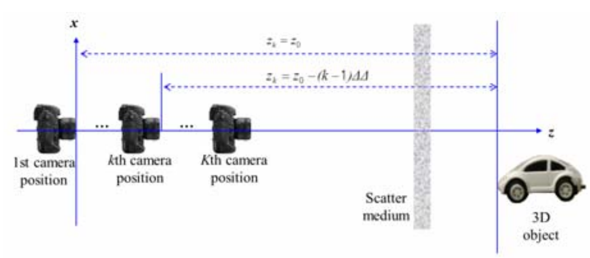

Figure-1. Pickup part of ADS.

Statistical processing of elemental images

When 3D object is located in scatter medium, the recorded image may contain severe scatter noises which can prevent the correct visualization and recognition for 3D object. In this paper, therefore, we wish to reduce them by using a statistical image processing. To do so, we apply a statistical image processing technique to the scattering elemental images. The detail process is described in Figure-2 [6]. The maximum-likelihood estimation (MLE), Gamma correction, and histogram matching were used. Finally, we obtain new scatter-reduced elemental images.

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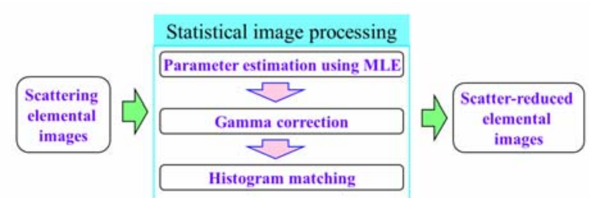

Figure-2. Statistical image processing for the recorded elemental images.

Recognition of ADS

In the proposed method, the third part is the computational reconstruction using the scatter-reduced elemental images. This is shown in Figure-3.

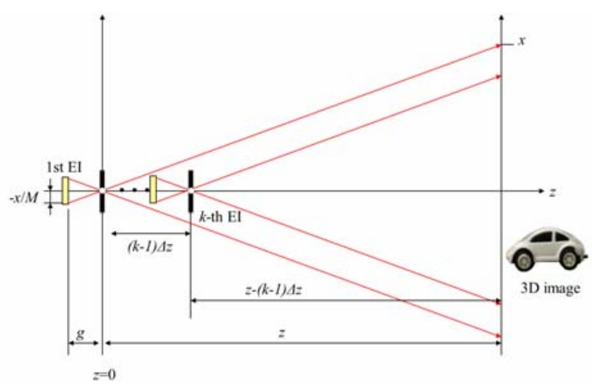

Figure-3. Ray diagram for computational reconstruction.

It is based on ray back-propagation through virtual pinholes. This reconstruction algorithm numerically implements the reverse of the pickup process. In other words, all elemental images are back projected and magnified by different magnification $M_k(z)$ if the reconstruction plane is located at z. Then, the reconstructed plane image $r(x, y, z)$ is the summation of all the magnified elemental images S^k and is given by

$$r(x,y,z)=\frac{1}{K}\sum_{k=1}^{K}S^k\left(\frac{x}{M_k},\frac{y}{M_k}\right) \quad (1)$$

Recognition process

In the last part of the propose method, the plane image $r(x, y, z)$ reconstructed at z distance from the computational reconstruction part are used for 3D object recognition. When a plane image of the target object is reconstructed at z distance, correlation is performed with the reference image f to recognize 3D object. Here we simply obtain correlation peak result from nonlinear correlation operation as given by

$$f\otimes^{\alpha} r = IFT\{|F|^{\alpha} exp(i\phi_F)\,|R|^{\alpha} exp(i\phi_R)\} \quad (2)$$

where α is the nonlinear parameter. F and R are the Fourier transformed of f and r, respectively. In Eq. (2), the correlation peak means the recognition performance between the 3D object and the reconstructed image.

EXPERIMENTS AND RESULTS

To demonstrate the proposed recognition method of a 3D object in scattering media, we carried out the optical experiments. The experimental setup is shown in Figure-4 where a 'car' object is positioned approximately 410 mm away from the first camera position. The camera is moved with the step of 5 mm and a total of K=41 elemental images are recorded within a total displacement distance of 200 mm. The first elemental image and the 41th elemental image are shown in Figure-4(c) and 4(d), respectively. To reduce the scatter noise in the elemental images, the statistical image processing technique was applied to them described in Figure-3.

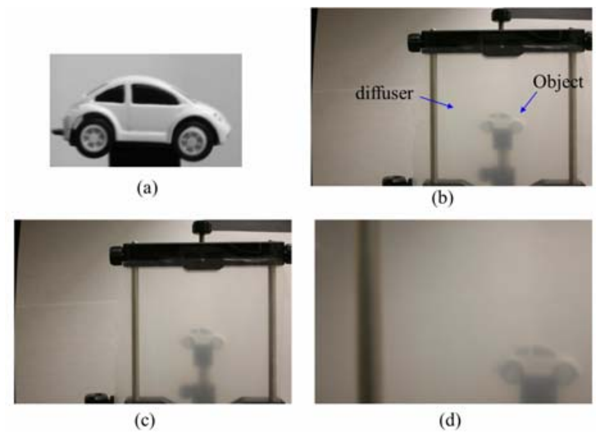

Figure-4. (a) Original object (b) Experimental setup. (c) 1st scattering elemental image (d) 41st scattering elemental image.

Figure-5 shows the example of the 21st elemental image produced by the statistical image processing technique. The 21st elemental image shown in Figure- 5(a) was scatter-reduced as shown in Figure-5(b). The statistical image processing was repeated to all the recorded elemental images. Then, we can obtain the 41 scatter-reduced elemental images. To reconstruct the 3D images, the scatter-reduced 41th elemental images were computationally back projected through virtual pinholes according to Eq. (4). The 3D images were obtained according to the reconstruction distance. A slice image is shown in Figure-5(c).

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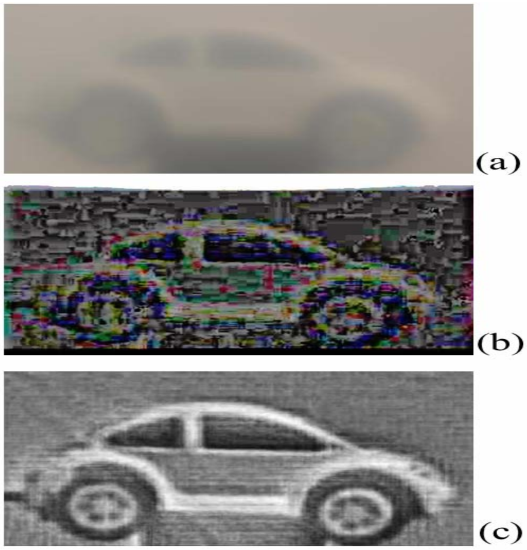

Figure-5. (a) ‘Car’ image within 21st elemental image (b) Statistically processed images (c) Computationally reconstructed plane image.

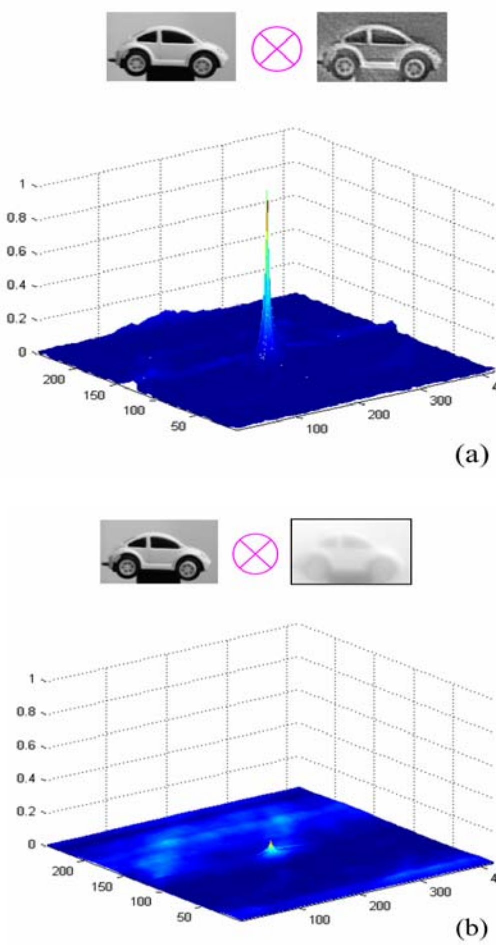

Figure-6. Nonlinear correlation results when α=0.7 (a) Proposed method (b) Conventional method.

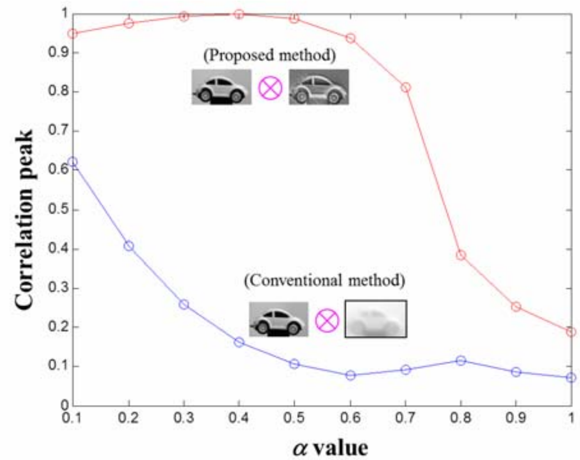

Figure-7. Nonlinear correlation results according to the α value.

To recognize the 3D object, the nonlinear correlation operation as described in Eq. (5) was used for the original reference image and the reconstructed plane image. The correlation results are shown in Figure-6. This result reveals that the scatter-reduced plane image provides the higher recognition performances compared with the scattered plane image for all α values.

Figure-7 shows the graph of the maximum correlation peaks according to the nonlinear parameter (α) in Eq. (2). This result reveals that the scatter-reduced plane image provides the higher recognition performances compared with the scattered plane image for all α values.

CONCLUSIONS

In conclusion, the ADS-based recognition method for a 3D object in scattering media was presented. The elemental images recorded by ADS method contain severe scattering noises. To reduce the scattering noises, we applied a statistical image processing algorithm to the scattering elemental images. Thus, we were able to obtain the improved 3D plane images using the digital reconstruction algorithm based on ray back-projection. Using them, we compare the correlation performance for the proposed method and the conventional method. We performed the optical experiments for the proposed method. The experimental results reveal that the proposed method is superior to the conventional method in terms of correlation operation.

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