Optics Communications 284 (2011) 3227–3233

Contents lists available at ScienceDirect

Optics Communications

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

Efficient compression of rearranged time-multiplexed elemental image arrays in MALT-based three-dimensional integral imaging

Ho-Hyun Kang [a], Byung-Gook Lee [b,*], Eun-Soo Kim [a]

[a] 3D Display Research Center, Dept. of Electronic Eng., Kwangwoon University, 447-1 Wolge-Dong, Nowon-Gu, Seoul 139-701, Republic of Korea
[b] Dept. of Visual Contents, Dongseo University, San69-1, Jurye-2Dong, Sasang-Gu, Busan 617-716, Republic of Korea

ARTICLE INFO

Article history:
Received 14 April 2010
Received in revised form 16 December 2010
Accepted 22 December 2010
Available online 21 February 2011

Keywords:
Integral imaging
Compression
Moving array lenslet technique
Elemental images

ABSTRACT

In this paper, an approach to efficiently compress the time-multiplexed EIAs picked up from the MALT-based integral imaging system is proposed. In this method, the time-multiplexed EIAs are rearranged by collecting the elemental images occupied at the same position in each EIA to enhance the similarity among the elemental images. Then, MPEG-4 is applied to these rearranged elemental images for compression. From the experimental results, it is shown that the average correlation quality (*ACQ*) value representing a degree of similarity between the elemental images, and the resultant compression efficiency have been enhanced by 11.50% and 9.97%, respectively on the average for three kinds of test scenarios in the proposed method, compared to those of the conventional method. Good experimental results finally confirmed the feasibility of the proposed scheme.

1. Introduction

Since the integral imaging scheme was proposed by G. Lippmann for the first time in 1908, it has been actively researched as a promising approach for the next-generation three-dimensional (3-D) imaging and display technology because it can provide us a real 3-D image with full-parallax and continuous-viewing points [1–8].

The integral imaging system is largely composed of two parts: pickup and reconstruction. In the pickup part, direction and intensity information of rays emanating from a 3-D object are spatially sampled through a pickup lenslet array and recorded by a 2-D image sensor. Here, the recorded image data is called an elemental image array (EIA) or elemental images which represent different perspectives of a 3-D object. On the other hand, in the reconstruction part, the recorded EIA is displayed on a 2-D display panel such as the liquid crystal display (LCD), and then rays coming from the EIA are redirected through a display lenslet array to form a real 3-D image.

But, this integral imaging scheme has suffered from several drawbacks such as low resolution, narrow viewing-angle and small depth for practical applications. Especially, reconstruction of a 3-D image in high-resolution from the picked-up elemental images is highly required in most applications. The resolution of the reconstructed 3-D image might be highly dependent on the number of picked-up EIs. Therefore, the resolution of the reconstructed 3-D image can be enhanced as the number of picked-up elemental images increases.

J.-S Jang and B. Javidi proposed a concept of moving lenslet array technique (MALT) based on time-multiplexing to pick up an increased number of elemental images for resolution improvement of the reconstructed 3-D images [4]. In the MALT-based integral imaging system, the position of a pickup lenslet array is vibrated in the lateral direction to increase the spatial sampling rate, which results in a vast increase of picked-up elemental images.

Even though a significant quantity of image data can be picked up at once in the MALT-based integral imaging system for reconstruction of a high-resolution 3-D image [4,9,10], we are facing a critical issue in handling such a large data in real-time for practical purpose such as storing on a media device or transmitting through a channel. In other words, it is necessary to compress the massive data of elemental images generated from the MALT-based integral imaging system for efficient storage and transmission.

Thus far, several approaches for compression of the picked-up EIA have been presented. In 2001, M. C. Forman et al. suggested a 3-D discrete-cosine transform (DCT)-based compression method for unidirectional integral imaging [11]. In 2004, S. Yeom et al. used a video compression algorithm of MPEG-2 for data reduction of the pick-up EIA, in which elemental images were modeled as the consecutive frames in a moving picture [12]. In 2005, J.-S. Jang et al. employed the Karhunen–Loeve Transform (KLT) algorithm for compression of the picked-up EIA, in which data statistics of the elemental images was considered for compression [13]. Moreover, in 2008, H.-H. Kang proposed a sub-image array (SIA)-based compression scheme, in which the picked-up elemental images were transformed into the sub-images for improving the similarity among the sub-images and then the KLT compression algorithm was applied to these sub-images [14].

* Corresponding author. Tel.: +82 51 320 1727.
E-mail address: lbg@dongseo.ac.kr (B.-G. Lee).

0030-4018/$ – see front matter © 2011 Published by Elsevier B.V.
doi:10.1016/j.optcom.2010.12.076

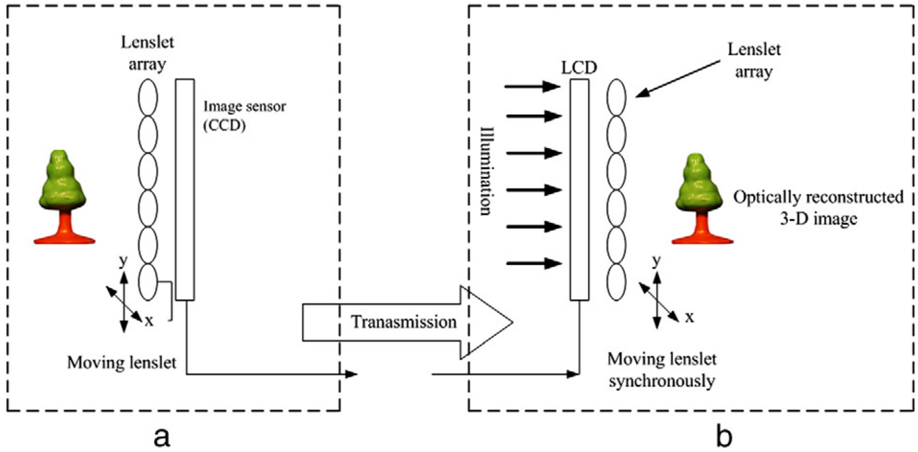

Fig. 1. Pickup and display setup in the MALT-based integral imaging system: (a) pickup process, and (b) display process.

In this paper, a novel approach to efficiently compress the time-multiplexed EIAs picked up from the MALT-based integral imaging system is proposed. In the proposed method, time-multiplexed EIAs are picked up with the MALT and they are rearranged by collecting the elemental images occupied at the same position in each EIA. Then, a compression algorithm of MPEG-4 is applied to these rearranged elemental images. Here, a rearrangement operation of the time-multiplexed EIAs can significantly increase the similarity among the elemental images, which may result in an increase of compression efficiency.

To show the feasibility of the proposed scheme, experiments are carried out and the results are discussed.

2. Review of the MALT

In general, the resolution of the reconstructed 3-D image in the integral imaging system can be determined by several system parameters including lenslet aberration, number of pixels in the image sensor and so on. Among them, one of the most fundamental factors that limit the resolution of the reconstructed 3-D image is the pitch of the lenslet arrays. This determines the ray sampling rate in the spatial dimension. From the Nyquist sampling theorem, the upper limit of the viewing resolution in the lateral direction is given by $\beta_{nyq} = l/2p$ in cycles per radian, where p is the pitch of the lenslet array in the lateral direction and l is the distance between the observation point and the display lenslet array [4]. To solve this limited viewing angle in the lateral direction, a concept of MALT was applied to the conventional integral imaging system.

Fig. 1 depicts the MALT-based integral imaging system. In the pickup part, the pickup lenslet array is vibrated in the lateral direction to increase the spatial sampling rate as shown in Fig. 1(a), in which the image sensor is kept to be fixed. The price we have to pay for the improved viewing-resolution in the MALT is that we have to increase the time response of the image pickup to accommodate non-stationary elemental images. For example, suppose the resolution improvement of a 3-D image n times, then we should pick up the elemental images at the $n \times n$ sampling points. Here, $n = p/s$ where s is the sampling interval. The pickup process is repeated within a lenslet pitch.

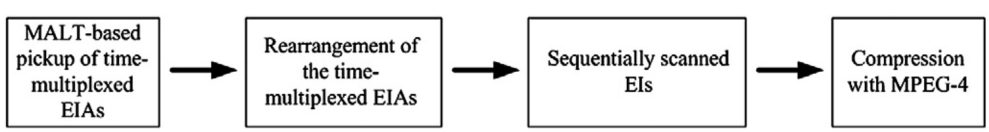

Fig. 2. Block diagram for compression of the rearranged time-multiplexed EIAs using MPEG-4.

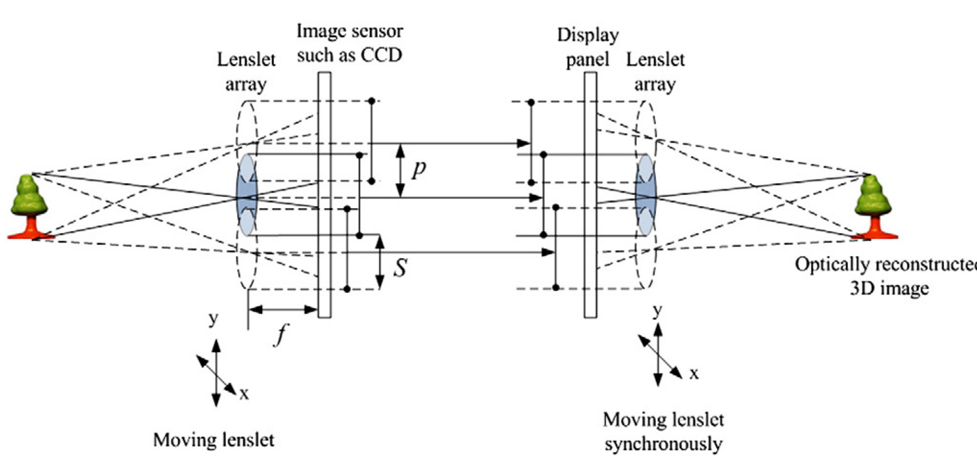

Fig. 3. Schematic for controlling the spatial ray sampling rate by adjusting the lenslet pitch.