International Journal of Applied Engineering Research ISSN 0973-4562 Volume 14, Number 1 (2019) pp. 250-253

Review and Comparison of Computational Integral Imaging Reconstruction

Joungeun Bae and Hoon Yoo*

Department of Computer Science, SangMyung University
Full Professor, Department of Electronics, SangMyung University

**Corresponding author*

Abstract

In this paper, we review and compare the methods of computational integral imaging reconstruction (CIIR). The integral imaging is a technique for recording and reconstructing three dimensional (3D) images using white light. Computational integral imaging reconstruction methods have been actively studied because it has no optical and physical limitation. Thus, it is used in the various application fields such as hologram generation and 3D objects recognition. Several enhanced computational integral imaging reconstruction methods have been discussed to improve the resolution of 3D images and to increase the feasibility in the applications. In this paper, we review and compare the enhanced computational integral imaging reconstruction methods.

Keywords: integral imaging, computational integral imaging

INTRODUCTION

Integral imaging is the technique for recording and reconstructing three-dimensional(3D) objects with white light. It was first proposed by Lippmann in 1908. It has a very useful structure for representing 3D images because it can easily pick up 3D images using a small lens array and then display it using the same lens array [1- 6]. Generally, integral imaging is divided into two steps of pickup and display. In the pickup method of the integral imaging, an elemental image is generated with a lens array and an image recorder. In the process of visualizing 3D objects, the elemental images are displayed on a display device and then projected onto the lens array.

Computational integral imaging reconstruction (CIIR) has been derived from optical integral imaging of pickup and reconstruction. This method is a 3D modeling of optically acquired elemental images in virtual (Figure 1). 3D images are reconstructed digitally, not the optical device, by modeling the geometrical optics principle of each element lens and lens array with the computer. Because CIIR technology has no optical and physical limitations, it can reconstruct elemental images in various ways. Thus, computational integral imaging reconstruction has been actively studied to improve feasibility in various application fields. For example, object recognition [7-8], encryption [9-10], bio-medical, etc. [11].

Recently, 3D computational reconstruction methods have been addressed to improve the visual quality of the reconstructed images. These methods reconstruct 3D view images using various novel approaches. Studies based on patch analysis have been proposed to reconstruct high-resolution three-dimensional images [12-16]. Techniques based on the pixel-to-pixel mapping scheme provide high-resolution reconstructed images when elemental image arrays have low-resolution [17-23]. In another approach, convolution-based reconstruction method methods have been actively studied [24-27]. The concept of convolution was employed to provide and control the 3D depth information of the elementary image arrays.

Computational integral imaging reconstructions have been actively studied to increase feasibility in practical applications. Thus, review and comparative analysis is required to evaluate. In this paper, we reviewed and compared the enhanced computational integral imaging reconstruction in the aspect of various approaches.

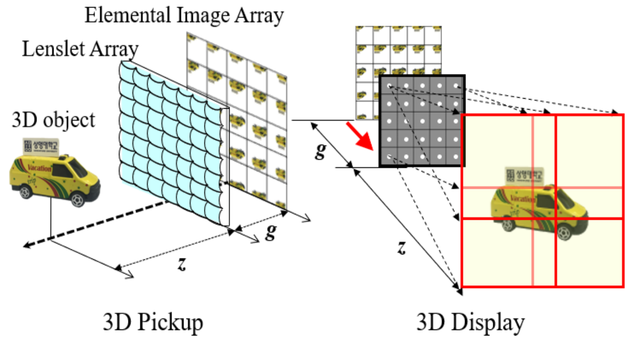

Figure. 1. Integral imaging (a) pick up (b) reconstruction

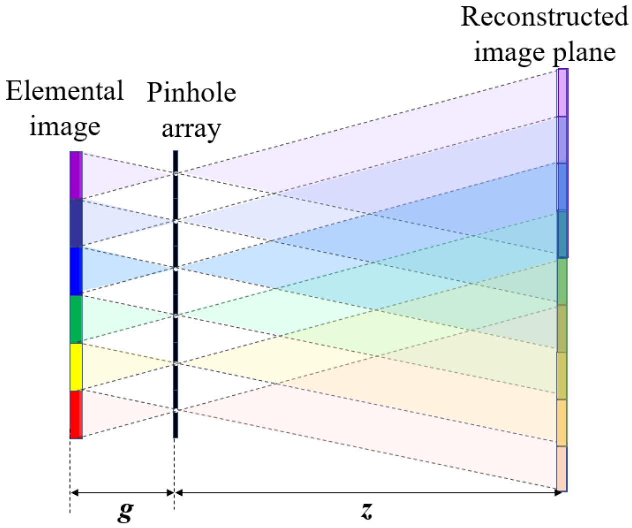

Figure. 2. Reconstruction in the CIIR

CONVENTIONAL METHOD OF COMPUTATIONAL INTEGRAL IMAGING RECONSTRUCTION METHODS

Computational integral imaging reconstruction (CIIR) is a method of digitally reconstructing a two-dimensional elemental image obtained during a pick-up process, rather than an optical method. Figure 2 shows the principle of a plane-based CIIR method for reconstructing images on a plane using a pinhole array model at distance *z*. At a fixed distance *z* from the pinhole array, each element image is back projected through the corresponding virtual pinhole array. The projected images are enlarged by the enlargement magnification *M*. *M* is determined by the ratio of the distance between the pinhole array and the reconstructed image plane and the distance between the pinhole array and the element images. ($M = z / g$) When $M > 1$, the projected images are superimposed on each other with enlarged adjacent element images at the projected image plane *z*. In order to reconstruct volumetric data of 3D, the same process as above is repeated at the distance corresponding to all reconstructed image planes.

Computational integral imaging reconstruction has the advantage of reconstructing 3D images without optical limitations. Enhanced computational integral imaging reconstruction studies have been presented in recently to increase resolution of reconstructed images and improve the feasibility in applications. To compare the advantages of these methods, we analyzed and discussed these methods in the next part.

REVIEW OF COMPUTATIONAL INTEGRAL IMAGING RECONSTRUCTION METHODS

Many studies have been discussed in order to efficiently use the limited resolution of recorded elemental images. The existing approach was moving the micro lens array or microscope to increase the spatial sampling rate at the pickup stage [12-13]. Otherwise, patch analysis-based research for reconstructing a three-dimensional image corresponding to the full resolution of an optical device at the reconstruction step has been discussed [14-16]. The patch analysis is similar to correspondence analysis, which determines two pixels that correspond to the same point of an object in another elemental image in depth extraction. Based on these points, view images are interpolated by patches. These methods can generate a view image at the full resolution of the recording device, but the quality of the reconstructed image is determined according to the accuracy of the depth map [14-15]. The paper has been published that reconstructs a three-dimensional image of maximum resolution from a recorded image with a single recording device without having to calculate the depth map [16].

Pixel to pixel mapping methods have been proposed as another approach to obtain high quality reconstructed images when the acquired elemental images have low resolution. These methods provide high resolution 3D images when compared with conventional computational integral imaging reconstruction methods for low-resolution elemental images [17-23]. In particular, new standard reconstruction algorithm based on the pixel-to-pixel mapping method, the pixel of elemental images rearrangement technique (PERT), has been studied [21]. This method re-arranges the pixels of the elementary image to provide a high-resolution reconstructed image but has a problem that the size of the reconstructed image is different from that of the optical reconstructed image. This is because the empty space in the back-projected plane is not considered, and PERT with space has been proposed [22]. This has the problem of having high memory usage and execution time. PERT using the convolutional (CPERT) method overcomes the problems of the existing PERT technology by providing a high-resolution restored image by reducing execution time and efficiently using the storage space [23].

Studies have been discussed with novel approaches using convolution properties during reconstruction [24-27]. This approach usually adjusts the depth resolution or obtains certain three-dimensional objects at a certain depth. When the properties of the convolution are applied to the elementary image, 3D depth information can be obtained [24]. In addition, this property can adjust the depth resolution, which controls the focus of a specific object at a specific depth through the definition of convolution property between periodic functions (CPPF) [25]. The window technique of the computational integral imaging reconstruction was interpreted as the convolutional property of the elemental image array [26]. It analyzes the artifacts occurring in the reconstruction process and improve the quality of reconstructed images. Finally, there have been studies to provide an immediate refocused reconstruction image by applying convolution with δ-function sequences [27]. This technique has the advantage of providing three-dimensional information of a specific object at a specific depth since it has an efficient structure for increasing the number of element image arrays.

Table 1 compares conventional and recent computational integral imaging reconstruction methods. It is the result of analyzing reconstruction methods at various approach. A patch analysis reconstruction can generate a view image at a full resolution of one recording apparatus from the elementary image array. If it is impossible to obtain a reconstructed image with a high resolution because the resolution of the elementary image array is low, the PERT approach is proper. Lastly, the depth information of a specific object at a certain position in the reconstruction process is possible with convolution approach methods.

Table. 1. Comparison of the CIIR

Approach	Resolution	Complexity	Applications
Conventional	low	low	3D display
Patch analysis	high	high	3D display
PERT	high	high	3D display
Convolution	low	high	3D object identification,

CONCLUSION

We have reviewed and compared the computational integral imaging reconstruction methods for reconstructing 3D images digitally. The various computational integral imaging reconstruction methods based on their novel approaches have been presented for practical use in various applications. We compared the methods and divided into categories such as patch analysis, PERT and convolution.

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