Viewing angle improvement of integral imaging three-dimensional display system using horizontal and vertical multi-directional projections and elemental image rearranging method with pepper and salt noise reduction

Md. Shariful Islam, Md. Tariquzzaman, Md. Abdur Razzaque

Abstract-This paper presents the viewing angle improvement of integral imaging (II) three-dimensional (3D) display system using horizontal and vertical multi-directional projections and elemental image (EI) rearranging method with pepper and salt noise reduction. Through this way, each elemental lens of micro lens array gathers horizontal and vertical multi-directional illuminations of multiple EI sets and produces multiple point light sources (PLSs) at the different positions in the focal plane and the positions of PLSs can be controlled by the projection angles. The viewing region is comprised of multiple diverging ray bundles that is broader than the conventional method owing to horizontal and vertical multi-directional projections of multiple EI sets. On the other hand, a conventional system provides a viewing area using only a single set of horizontal or vertical multidirectional EI projection. As a result, the viewing angle and the image quality of the 3D reconstructed image is enhanced.

Index Terms— Integral Imaging, Elemental image, Microlens array, Multi-directional projections, Three-dimensional display, Viewing angle improvement, Salt and pepper noise reduction

1 INTRODUCTION

Integral imaging (II) is a striking autostereoscopic three-dimensional imaging and display technique that was firstly introduced by Lipmann named as integral photography [1] in 1908. II technique consists of two parts, pickup and reconstruction [2], [3], [4], [5], [6] as shown in Fig. 1. In the pickup process of II, direction and intensity information of the rays coming from a 3D object are spatially sampled by use of a lens array (or pinhole array) and two-dimensional (2D) image sensor. The lens array composed of many convex elemental lenses is positioned immediately in front of the photographic film as a capture device.

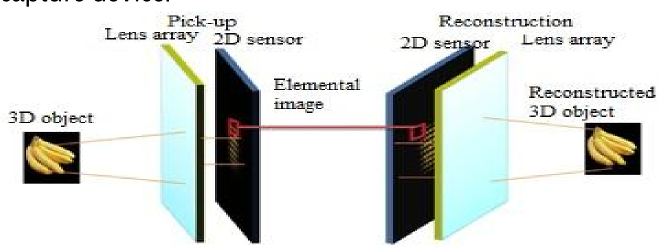

Fig. 1: Integral Imaging for pick-up and reconstruction

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The captured image is composed of numerous small elemental images, which are imaged by lens array with their number corresponding to that of the elemental lenses. Therefore, a size of elemental image is equal to a size of elemental lens. A real image, which is pseudoscopic (depth-reversed) image [7], [8], [9], [10], is reconstructed through the lens array when the elemental image is displayed on a 2D display device. There are numerous advantages of II technique, namely; full colour, full parallax, natural depth perception with relatively low eye-fatigue, real 3D image with continuous view point and specially does not require any extra glasses or tracking devices to view the 3D image. Although having a number of attractive benefits, II has been suffering some crucial disadvantages. One of them, narrow viewing angle is a major problem. To mitigate this problem, a huge work has been done by the many researchers [11], [12], [13]. Recently, we have been reported a technique to improve the viewing angle of II three-dimensional (3D) display system by using multiple illuminations [14]. We proposed a method through this paper to enhance the viewing angle of II system using horizontal and vertical multi-directional projections and elemental image rearranging method with pepper and salt noise reduction. The viewing region is comprised of multiple diverging ray bundles that are broader than the conventional method owing to horizontal and vertical multi-directional projections of multiple EI sets. On the contrary, a conventional system provides a viewing area using only a single set of EI projection. The same size of micro lens pitch with horizontal and vertical multi-directional projection of EIs causes an EI disparity at the EI plane. EI rearranging method is applied to the EI generation algorithm to prevent EI disparity. In our proposed II system permit the reconstruction of a three-dimensional image with broader viewing angle than a conventional II system because of the angles of horizontal and vertical mult-idirectional projections and the number of EI sets are used. To implement the proposed II system, modern depth cameras and state of the art projectors are used for detaining three-dimensional object information with horizontal and vertical multidirectional perspective and projecting the multiple sets of elemental images with multidirectional projection angles correspondingly.

2 PROPOSED METHOD

In this paper a viewing angle improvement of II system on horizontal and vertical multi-directional projections including a directional horizontal and vertical elemental image generation with rearranging (DHVEIGR) algorithm with pepper and salt noise reduction is proposed. Our proposed system consists of three main sections, namely: (i) 3D entity information extraction with colour and depth (ii) directional elemental image (horizontal and vertical) generation using DHVEIGR algorithm and (iii) 3D image reconstruction from side to side a horizontal and vertical multi-directional projection type II display system with pepper and salt noise reduction. The fundamental theory of viewing angle improvement using horizontal and vertical multi-directional projections is illustrated in Fig. 2. In this system, horizontal and vertical multi-directional multiple sets of EIs are projected on the micro lens array including a sequential projection scheme. For the multi-directional EI projections, each micro lens of the lens array produces a number of point light source [14], [15] as the same numbers of HEI and VEI sets are projected. The angle of the diverging rays as well as the positions of the point light sources can be guided by the directional projection angle. To improve the viewing angle and resolution the directional projection angle is significant in this method.

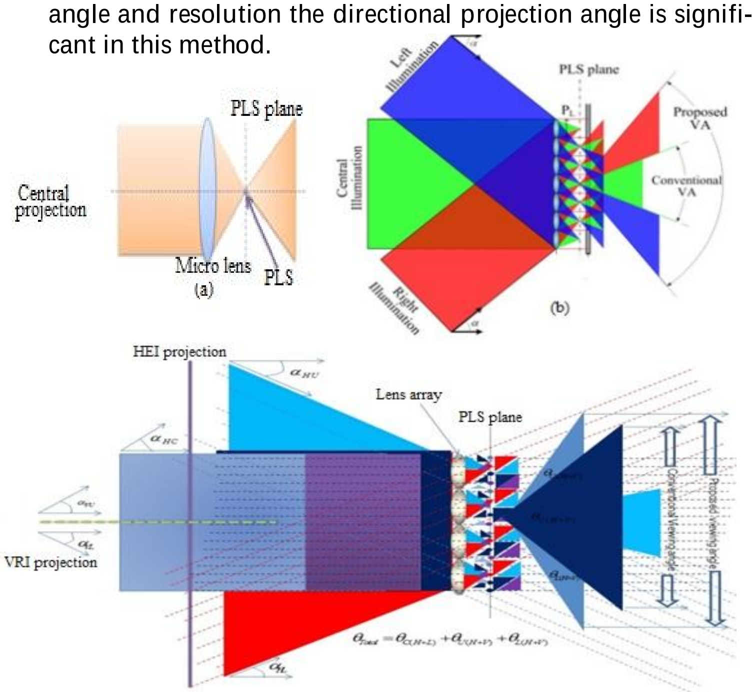

Fig. 2: Rules of Viewing angle improvement using multi-directional projections of EIs for (a) Central one directional (b) three-directional projections and (c) horizontal and vertical multi-directional projections.

In the proposed method, the projection angles are considered two or three directional both horizontal and vertical projections for the same number of EIs are narrated in Fig. 2 (b) and 2 (c) successively. In the case of three dimensional projections, the projection angles are computed using the following equtions:

$$\alpha_0 = 0, \alpha_L = \tan^{-1}\left(\frac{P_L}{f}\right), \alpha_R = -\tan^{-1}\left(\frac{P_L}{f}\right) ....(1)$$

where α_L and α_R are the left and right directional projection angles, p_L and f are the pitch and the focal length of micro lens. Then the viewing angle can be determined by the equation

$$\theta_{Total(Conventional)} = 2\tan^{-1}\left(\frac{3P_L}{2f}\right) \cong 3\theta ...(2)$$

where

$$\theta = 2\tan^{-1}\left(\frac{P_L}{2f}\right)$$

For the proposed horizontal and vertical multi-directional projection angles can be determined by the following equations:

$$\alpha_{HU} = \tan^{-1}\left(\frac{P_L}{f}\right), \alpha_{HL} = -\tan^{-1}\left(\frac{P_L}{f}\right), \alpha_{VU} = \tan^{-1}\left(\frac{P_L}{f}\right), and, \alpha_{VL} = -\tan^{-1}\left(\frac{P_L}{f}\right)$$

where $\alpha_{C(H+V)}$ is the horizontal and vertical center projection angle α_{HU} is the horizontal upper projection angle, α_{HL} is the horizontal lower projection angle, α_{VU}, α_{VL} are the vertical upper and lower positional projection angles. The viewing angle (proposed) can be determined by the equation:

$$\theta_{Total} = \theta_{C(H+L)} + \theta_{U(H+V)} + \theta_{L(H+V)} = 2\tan^{-1}\left(\frac{4p_L}{2f}\right) \cong 4\theta ....(3)$$

From the mathematical calculation refering (2) and (3) noticeable that obtained angle is greater than conventional II system. For the future, the viewing angle may be written as

$$\theta_{future} = 2\tan^{-1}\left(\frac{np_L}{2f}\right) \cong n\theta$$

The proposed system configuration is shown in Fig. 3.

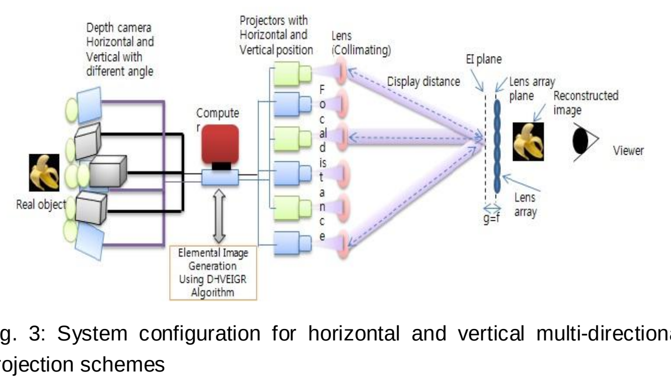

Fig. 3: System configuration for horizontal and vertical multi-directional projection schemes

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3 INFORMATION CAPTURING SYSTEMS FROM THE 3D OBJECT

In our proposed II system, primarily 3D object's information, namely: colour and depth are extracted by using depth camera (state of the art sensor). After that the extracted data of the 3D object are used in directional elemental image generation for horizontal and vertical multidirectional projections through the display system. This phenomenon is illustrated in Fig. 4. KINECT sensor (Resolution 512×424, Field of View 70×60 and Frequency 30 Hz) which has higher depth fidelity and a significantly improved noise floor is used to gather 3D entity information

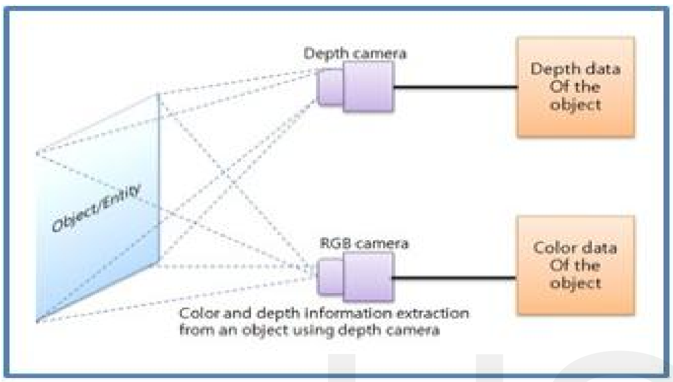

Fig. 4: The extraction process of colour and depth information of 3D object

The state of the art KINECT sensor is consists of two kinds of sensor, one is true colour (RGB) camera that is responsible for capturing the colour image of the object and another is called depth camera which is responsible for capturing the depth information of the real 3D object. By having the all information (colour and depth) of the real object, the directional elemental image is generated using DHVEIGR algorithm based on pixel mapping algorithm [16]. In Fig. 5. it is shown that the extracted information of the real 3D objects that is snapped by the state of the art depth camera.

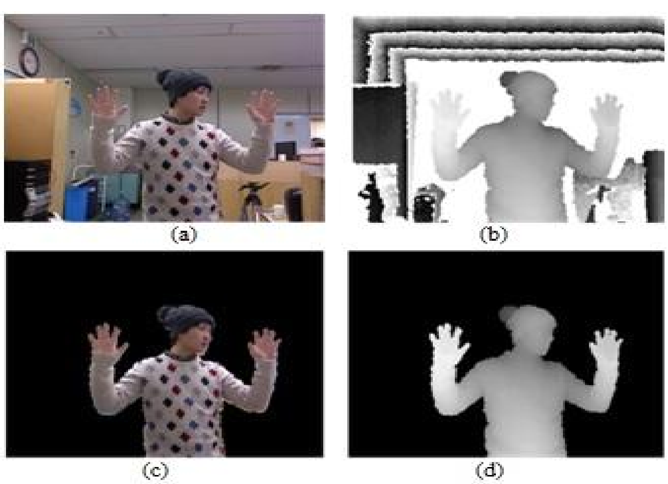

Fig. 5: Extracted information of 3D objects (a) true image (b) depth information of true image (c) colour information region of interest (ROI) (d) ROI depth information

4 THE PROCESS OF ELEMENTAL IMAGE GENERATION

Elemental image sets can be created by using the DHVEIGR algorithm from the extracted information (colour and depth) of the 3D real object based on pixel mapping algorithm regarding as the directional projection geometry of each pixel. Because of the multi-directional projections of EIs it's very natural to produce EI mismatch on the projection plane of the proposed method. For solving the aforementioned problem, an EI rearranging function is added in the DEI generation algorithm with respect to horizontal and vertical multi-directional projection angles. For multi-dimensional EI generation using several horizontal and vertical multi-directional projection angles is shown in Fig 6.

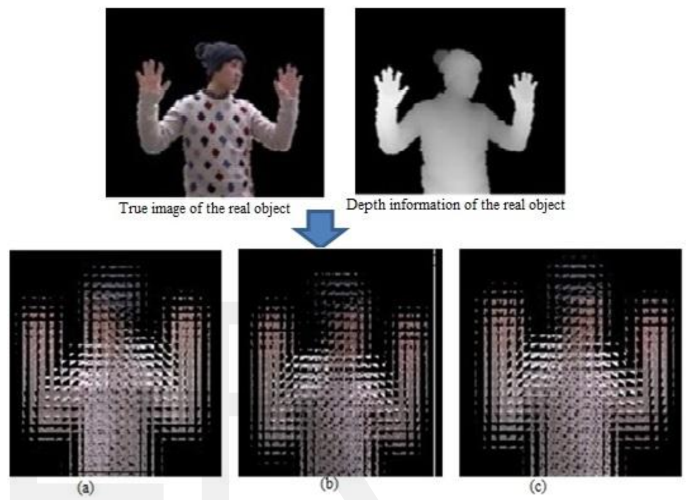

Fig. 6: EI generation using horizontal and vertical multi-direction projections for (a) -20° directional projection (b) 0°(central) projection and (c) 20° directional projections using DHVEIGR algorithm

5 RESULTS AND DISCUSSION

To prove the proposed method some basic experiments are conducted. For directional elemental image generation used the colour and depth information which extracted from the KINECT sensor and HVDEIGR algorithm, a general (central projection) experiment is conducted for reconstruction of a 3D image as shown in Fig. 7.

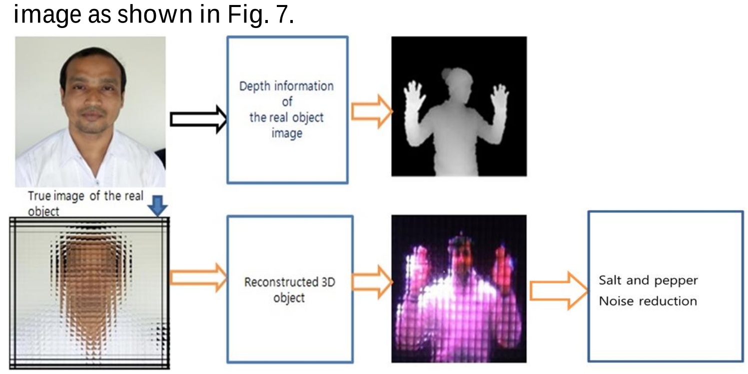

Fig. 7: 3D image reconstruction of 3D object using a conventional projection type II system with color and depth information generated EIs

Obtained results from the experiment confirmed the possibility of the reconstruction of 3D image by using the extracted colour and depth information of real entity through the proposed projection type II technique. After that several trials are conducted to verify the reconstruction of 3D image by using horizontal and vertical multi-directional projection schemes and to confirm the feasibility of the improvement of the viewing angle of the proposed II system with pepper and salt noise reduction. As an initial experimental justification, only some experiment is conducted with multi-directional projection angles such as 0^0, 20^0, and -20^0 according to the figures, Fig 2. (a) , 2. (b) and refering (1) , (2) respectively. In fig 8. shown the reconstructed 3D images for 0° (central for both horizontal and vertical) projections viewed from the different viewing positions (horizontal left and rightmost positions) that ensures the possibility of the 3D reconstruction applying the colour and depth information from the object using DHVEIGR algorithm and reconstructed into a projection type II system with image noise (pepper and salt) reduction technique. Fig 8. also presented the reconstructed 3D images viewed from different positions (horizontal and vertical) for 20^0 and -20^0 multidirectional projections that ensure the possibility of the viewing angle improvement using horizontal and vertical multi-directional projections with DHVEIGR algorithm followed by the Fig 2 (c) and refer to (3).

Fig. 8: Reconstructed 3D images for horizontal and vertical multi-directional projections using different viewing angles

In Fig 9. Shows a noise removing technique is applied on reconstructed 3D images. This technique is affected for two phases. In the first phase, adaptive median filter is used to identify pixels which are likely to be degraded by noise. In the second phase, the image is restored using a specialized regularization method that applied to those selected noise.

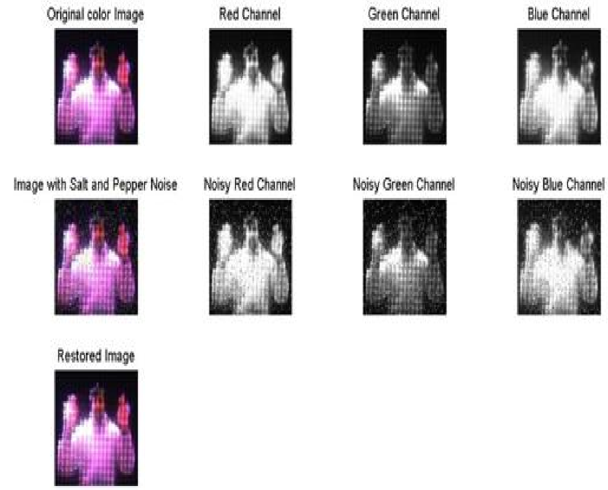

Fig. 9: Reconstructed 3D image using salt and pepper noise reduction

By applying this technique it is possible to remove salt and pepper noise with noise levels high as 85%. So, reconstructed 3D image quality is enhanced.

6 CONCLUSION

On the basis of aforementioned discussion and the some simulation results as well as laboratory experiments, it can be summarized that the viewing angle improvement of II 3D display system can be implemented by using horizontal and vertical multi-directional projections and EI rearranging method with DHVEIGR algorithm including salt and pepper noise reduction.The simulation and experimental result of Fig. 7. Illustrate the probability of the reconstruction of 3D image by applying colour and depth information of the real 3D object extracted by underlying sensor as well as salt and pepper noise reduction. The Figs. 8 (b) and (c) shows that the reconstructed 3D images are originated using horizontal and vertical multi-directional (20^0 and -20^0) EIs projection scheme in which the viewing angle of 3D display improved significantly refer to (3). Finally, the reconstructed 3D image noise is removed by applying a salt and pepper noise removing technique, hence reconstructed 3D image quality is enhanced.

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REFERENCES

[1] M.G. Lipmann, "Epreuves reversibles donnant la sensation du relief", J. Phys, 7, 821-825, 1908.

[2] F. Okano, H. Hoshino, J. Arai, and I. Yuyama, (1997) "Real-Time Pickup Method for a Three Dimensional Image Based on Integral Photography," Appl. Opt., vol. 36, pp. 1598-1603.

[3] Y.-W. Song, B. Javidi, and F. Jin, (2005) "3D Object Scaling in Integral Imaging Display by Varying the Spatial Ray Sampling Rate," Opt. Express, vol. 13, pp. 3242-3251.

[4] F. Okano, J. Arai, K. Mitani, and M. Okui, (2006) "Real-Time Integral Imaging Based on Extremely High Resolution Video System," Proc. of IEEE , vol. 94, pp. 490-501.

[5]] J. Arai, F. Okano, H. Hoshino, and I. Yuyama, (1998) "Gradient-index Lens Array Method Based on Real-time Integral Photography for Three-dimensional Omages," Appl. Opt., vol. 37, pp. 2034–2045.

[6]] R. Cuenca, A. Pons, G. Saavedra, M. Corral, and B. Javidi, (2006) "Optically-Corrected Elemental Images for Undistorted Integral Image Display," Opt. Express, vol. 14, pp. 9657-9663.

[7] N. Davies, M. McCormick, and L. Yang, (1998) "Three-Dimensional Imaging Systems: A New Development," Appl. Opt., vol. 27, pp. 4520-4528.

[8] Y. A. Dudnikov, "Elimination of Image Pseudoscopy in Integral Photography, (1971) " Opt. Technology, vol. 38, pp. 140-143.

[9] S.-W. Min, J. Hong, and B. Lee, (2004) "Analysis of an Optical Depth Converter Used in a Three-Dimensional Integral Imaging System," Appl. Opt., vol. 43, pp. 4539-4549.

[10] B. Lee, J.-H. Park and S.-W. Min, (2006) "Three-Dimensional Display and Information Processing Based on Integral Imaging," in *Digital Holography and Three-Dimensional Display,* (Springer, New York, USA, 2006), pp. 333-378.

[11] Hwi Kim, Joonku Hahn, and Byoungho Lee, "The use of a negative index planoconcave lens array for wide-viewing angle integral imaging", Optical society of America, 2008

[12] R. Martinez-Cuenca, H. Navarro, G. Saavedra, B. Javidi and M. Martinez-Corral, "Enhanced viewing-angle integral imaging by multiple-axis telecentric relay system", Optical Society of America, 2007.

[13] J. -H. Park, J. Kim, J.- P. Bae, Y. Kim, and B. Lee, (2005) "Viewing Angle Enhancement of Three-Dimension/Two-Dimension Convertible Integral Imaging Display Using Double Collimated or Noncollimated Illumination," Jpn. J. Appl. Phys, vol. 44, pp. 991-994.

[14] Y. Kim, J. Kim, J. M. Kang, J. H. Jung, H. Choi and B. Lee, "Point Light Source integral imaging with improve resolution and viewing angle by the use of electrically movable pinhole array", Opt. Express 15, 18253-18267, 2007

[15] Md. S. Islam, Md. Tariquzzaman, Md. Z. Islam, "Integral Imaging three-dimensional (3D) display with wide-viewing angle using multiple illuminations ", IJCI, ISSN: 2277-548X (online), Vol.3, No.4, 2014.

[16] Md. Shariful Islam, Md. Tariquzzaman, "Computer Generated Integral Imaging (II) Using Depth Camera", International Journal of Computer Science and Information Technology Research (IJCSITR), ISSN 2348-120X (online), Vol. 03, Issue 02, pp: (256-263), April-June 2015.