Resolution-Enhancing Integral-imaging-based Light Field displays by recombining subpixels

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As a new generation of display technology, VR/AR can bring people a realistic 3D experience, and it has been used in the military, education, medical, entertainment, and other fields. However, the depth cues of VR/AR devices are all provided by binocular parallax, which will cause the eyes to converge, and accommodation conflict (VAC) bring visual fatigue. In order to achieve true-3D display without VAC, light field display[1], multi-focal display[2], holographic display[3], etc., are proposed. Light field display is considered the most promising for commercialization due to its adjustable monocular depth, compact and lightweight devices.

However, the resolution of Integral imaging Light Field Displays (In-Im LFD) is very low because multiple pixels' reconstructed voxels are integrated. Predecessors have proposed many methods to improve resolution. J.-S. Jang and B. Javidi[4] proposed to use two synchronously moving micro-lens arrays to acquire and display images, increasing the sampling rate to improve the resolution. J. -Y. Wu et al.[5] proposed a new type of e-shifting device that uses a TN switch and a birefringent quartz plate to quickly switch the light between different polarization states, shifting the diagonal by half the pixel size to achieve resolution enhancement.

In this work, We use the subpixels recombination algorithm to triple the resolution. Figure1 (a) shows the principle of In-Im LFD. A micro-lens array is placed in front of the microdispay. Each lens corresponds to an element image. The reconstructed voxel is integrated by multiple vector rays generated by the chief rays emitted by the pixels in different element images passing through the center of the corresponding lens. We can use algorithms to change the reconstructed depth plane (RDP) position to place the 3D scene we need. For subpixels recombination in Figure1(b), the voxel is formed similarly to the traditional In-Im LFD display, but the subpixels provide its RGB value under different element images. In order to solve the problem of light sampling error in subpixels recombination, we found the zero sampling error plane, as shown in Figure 2.

$$\frac{D}{\left(N\pm\frac{1}{3}\right)\times P}=\frac{L_R}{L_R+g} \quad (1)$$

The voxel 1 on the RDP comes from the superposition of three subpixels of RGB under micro-lens 1, 2, and 3. In order to make the chief rays of these three subpixels perfectly intersect in the RDP, equation 1 should be satisfied. D is the lens aperture, L_R is the RDP position, P is the pixel length, and N is a positive integer. All voxels on this plane should satisfy this formula. We can get the highest resolution on these planes. The simulation uses zemax software to reconstruct a voxel. As shown in Figure 4, it can be seen that using the traditional method to reconstruct a single voxel to a human eye angle is about 5 arc minutes corresponding to 12 Pixel per degree(PPD), using the subpixels reconstruction method for a single voxel to human eye angle is about 3 arc minutes corresponding to 20PPD. We can see the increase in resolution.

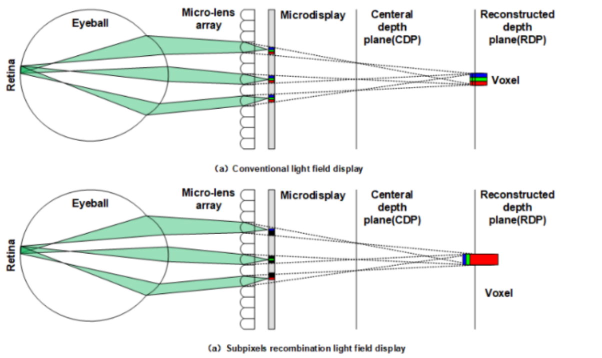

Fig. 1. Principle of integrated imaging light field display:(a) Conventional type (b)subpixels recombination type

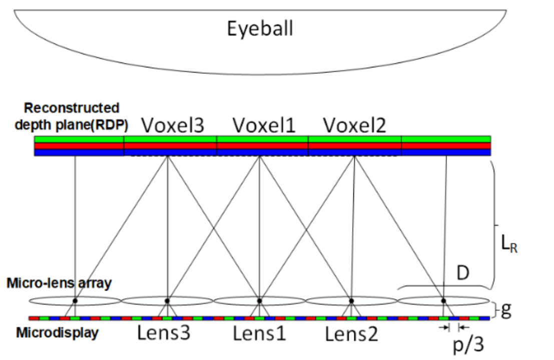

Fig. 2. Subpixels recombination zero sampling error surface

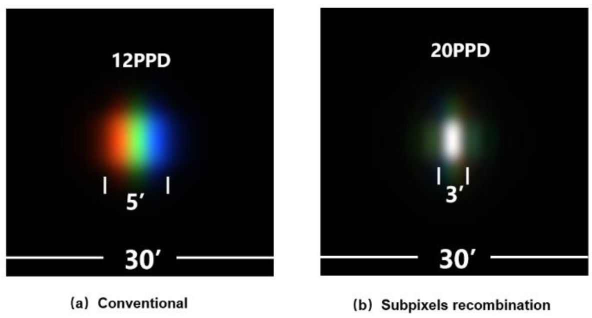

Fig. 3. Zemax Simulation results: （a）Conventional In-Im LFD (b)Subpixels recombination In-Im LFD

[1] Z. Qin, Y. Zhang, and B.R. Yang. Opt. Express 29, 7342-7360 (2021).

[2] J. P. Rolland, M.W. Krueger, and A. Goon. Appl. Opt. 39, 3209-3215 (2000).

[3] H. Kim, S. Lee, M. Piao, N. Kim and J. Park. T IEEE International Conference on Consumer Electronics (ICCE), 2015, pp. 132-133(2015).

[4] J. Jang and B. Javidi. Opt. Lett. 27, 324-326 (2002).

[5] J.-Y. Wu et al, JSID 26, 269 (2018).