Efficient sub-pixel based light field reconstruction on integral imaging display

Shaohui Jiao[§*] Haitao Wang[‡] Mingcai Zhou[‡] Xun Sun[‡] Tao Hong[‡]
Intel China Research Center[§] Samsung Research Center-Beijing, SAIT China Lab[‡]

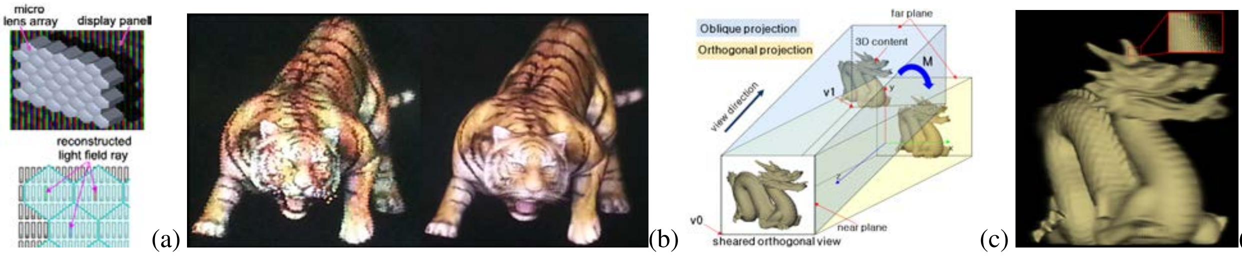

Figure 1: (a) Integral imaging display with sub-pixel based light field reconstruction. (b) Comparison of captured 3D imageries on traditional (Left) and proposed (Right) integral imaging display. (c) Shear transformation on duplicated content. (d) Integral image result.

1 Method Overview

Autostereoscopic displays outperform current stereoscopic displays by providing enhanced spatial understanding of 3D content through perceptual cues for both stereo and motion parallax. Integral imaging (II) display is one of the primary types of autostereoscopic display with advantage that 4D light field can be successfully reconstructed. However, it suffers from the limitations of both the reduced spatial resolution and the lack of involved real-time content generation strategies. In this paper, we advance the traditional II display with an efficient sub-pixel based light field reconstruction method, which can achieve 3D imagery with much higher spatial resolution in real-time speed.

• **Sub-pixel based light field reconstruction.** A high-density micro lens array is employed in our II display to realize high spatial resolution. To keep the same horizontal angular resolution, the lenslet's size is elaborately designed to enable the light field reconstruction based on sub-pixels. As shown in Figure 1(a), the width of a single lenslet is as 8 times as the sub-pixel' width, thus, one light field ray can be reconstructed by three different sub-pixels behind adjacent lenslets. Compared to traditional II display, which employs the pixel-based light field reconstruction method, higher spatial resolution can be realized owing to our proposed method. The comparison of captured 3D imageries is shown in Figure 1(b).

• **Efficient light field rendering.** In existing II display, speed performance is generally a significant bottleneck because of the high computational expense of light field rendering. Light field is generally rendered as multiple sheared orthogonal views (MSOV) [Yang et al. 2005] via several render passes, which are reduced to only two passes by our proposed pipeline. During the first pass, 3D content is duplicated on geometry shader to acquire the rendered result of reference views and their corresponding depth maps. Here, shear transformation $\mathbf{M}$ is performed on the duplicated 3D content, as shown in Figure 1(c). The parameters of shear transformation is computed according to the original oblique projection, as defined in equation(1). Sheared 3D contents are then translated to predetermined view positions so that multiple reference views are rendered in a single pass by one orthogonal projection. In the second pass, to compute intermediate views between the reference views, the 3D image warping is introduced. Although two-pass strategy is employed, the problem of increased data burden caused by geometry duplications is greatly alleviated and the generation of MSOV is efficiently accelerated.

$$\mathbf{M}^{s}_{(x,y,z)} = \begin{bmatrix} 1 & 0 & K_1 & 0 \\ 0 & 1 & K_2 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, K_1 = -\frac{\mathbf{v1}.x - \mathbf{v0}.x}{\mathbf{v1}.z - \mathbf{v0}.z}, K_2 = -\frac{\mathbf{v1}.y - \mathbf{v0}.y}{\mathbf{v1}.z - \mathbf{v0}.z}. \quad (1)$$

The MSOV are regarded as the target light field for II display. To acquire the final result of integral image, as shown in Figure 1(d), the MSOV are re-arranged at sub-pixel level on the fragment shader according to a predefined index texture, which records the correct remapping coordinates for re-arrangement.

2 Results and Conclusion

Table 1: Comparison of frame rates(fps) and render passes(p).

Model	Dragon/871k	Bunny/70k	Tiger/28k	Phone/20k
Ref[1]	13fps/16p	36fps/16p	169fps/16p	184fps/16p
Ref[2]	28fps/1p	81fps/1p	343fps/1p	386fps/1p
Ours	60fps/2p	124fps/2p	480fps/2p	491fps/2p

Table 1 shows the performance of proposed GPU-accelerated rendering pipeline with different models of 16 rendered MSOV (each at resolution of 250x250) on a commodity PC of Intel Duo Core 2.83GHz with 4GB memory, and NVIDIA Geforce GTX680. The experimental result demonstrates the high speed performance of our method. In the aspect of reconstructed spatial resolution, [Jiao et al. 2013] achieves only 125x125 while the proposed method can obtain 250x250 at the same integral image size.

In conclusion, our method outperforms existing techniques in both reconstructed spatial resolution and rendering speed.

Acknowledgements - This work was done when Shaohui Jiao was at Samsung Advanced Institute of Technology (SAIT) China Lab.

References

YANG, R., HUANG, X., AND CHEN, S. 2005. Efficient rendering of integral images. *Proceedings of SIGGRAPH'05, poster*

JIAO, S., WANG, X., ZHOU, M., LI, W., HONG, T., NAM, D., LEE, J., WU, E., WANG, H., AND KIM, J. 2013. Multiple ray cluster rendering for interactive integral imaging system. *Optics Express 21*, 10070–10086.

*e-mail:shaohui.jiao@intel.com

SIGGRAPH 2014, August 10 – 14, 2014, Vancouver, British Columbia, Canada.

ACM 978-1-4503-2958-3/14/08