Real-Time Computer-Generated EIA for Light Field Display by
Pre-Calculating and Pre-Storing the Invariable Voxel-Pixel Mapping

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Abstract
The elemental image array (EIA) for light field display especially integral imaging light field display was reliant on a virtual camera array, novel sampling algorithms, high-performance hardware or corresponding complex algorithms, which hinder its application. Without sacrificing accuracy and precision, we innovate a novel set of algorithm to achieve video-level EIA generation. The invariable voxel to pixel relationship is pre-calculated and pre-stored as a lookup table or mapping. Benefiting from the very lookup table, voxel array could be fast mapped to an EIA without being contingent upon any high-end hardware.

I.Introduction
Virtual reality (VR) and augmented reality (Augmented Reality) 3D display technologies are widely used in military, medical, entertainment, education and other fields. The traditional implementation method utilizes the principle of binocular parallax to generate three-dimensional effects through binocular vergence. However, due to the lack of depth information in the light emitted by the screen, the focus of the eyes does not match the sense of depth, which leads to Vergence-Accommodation Conflict (VAC), which causes visual fatigue for the viewer, and causes dizziness and discomfort after long-term viewing.

In order to realize true 3D display without VAC, a variety of implementation methods have been invented, which can be roughly divided into integrated imaging light field display, holographic display, volume 3D display, adaptive zoom and other methods according to the imaging principle [1-3]. Among them, the integrated imaging light field display has become the focus of the next-generation 3D display technology due to its advantages of simple and easy hardware implementation, lightness and thinness, and continuously adjustable depth.

At present, one of the main bottlenecks of this technology is that it is difficult to achieve low computational complexity rendering of target images, and to realize real-time interaction between users and virtual environments and real scenes. The integrated imaging light field display system usually includes a high-resolution display and a micro-imaging array. The two-dimensional image displayed on the
display is called an Elemental Image Array (EIA, Elemental Image Array). Different parts of the EIA are displayed in the micro-imaging array. The three-dimensional space is projected to different directions and integrated to form a three-dimensional image. In order to generate the EIA, the mapping is generally performed based on the viewpoint of the tracing light, and the image information carried by the light corresponding to each pixel on the EIA is calculated, that is, the luminance and chromaticity information corresponding to the mapping. This algorithm has a large amount of computation and a slow response speed, which cannot meet the needs of human-computer interaction, which limits the application and popularization of light field display.

At present, previous methods have proposed various improvements from the perspectives of hardware, algorithms and both: the use of 3D scanning technology, combined with cloud computing and GPU compression algorithms is considered a solution; based on Monte Carlo rays and fovea It can also achieve fast rendering by simulating the propagation of a certain amount of light; using the lens to do multiple refractions can realize the reconstruction of long-distance continuous depth 3D images; or using different sampling and ray tracing algorithms, such as Viewpoint Vector Rendering (VVR), extracting multi-view images, and reconstructing the 3D light field accordingly. Of course, there are many other relatively niche methods at home and abroad, such as combining specific renderers and scripts, and high-dimensional spatial feature regression calculations.

However, the existing image rendering technologies for virtual reality and augmented reality have one or more of the following shortcomings, making real-time rendering difficult to achieve:

1. It is too dependent on hardware computing power and needs to be combined with high-cost computing technology, which is difficult to achieve in wearable devices;
2. The application scenarios are limited, and it is not suitable for various integrated imaging displays;
3. The unit rendering time of the rendering machine (the time to render a single image) is too long, making it difficult to achieve real-time rendering;

The existing mainstream methods to improve the rendering speed of the light field, such as combining GPU compression algorithms and cloud computing, have problems of high rendering cost and high computing power cost; improving the basic optical path, such as adding a transflector, has a large volume and is difficult to achieve. The problem of carrying; using image graphics related algorithms to reduce the number of sampled rays, there are problems of reduced resolution and reduced viewing angle. Other methods all have one or more of the four defects listed in the "Background Art". This paper provides a real-time rendering algorithm based on integrated imaging light field. The algorithm is based on four main steps, namely:
① Calculate the corresponding positional relationship between all spatial volume pixels and the corresponding two-dimensional sub-pixels of the display;
② Input an image containing depth information, that is, an image containing both image information and depth information;
③ Generate a texture map by downsampling the image to a specific position;
④ Traverse all the spatial volume pixels in the texture map, and quickly generate real-time conversion and filling of the luminance and chromaticity information of the unit image array 3D image through the look-up table method.

Since the corresponding voxel position information of each unit image is pre-computed and stored, each rendering only needs to perform necessary downsampling and mapping of 3D image information based on the look-up table method, which greatly reduces the computational complexity and calculation amount.

II. Example

Video-level rendering rates can be achieved, and there are no special requirements for computer performance.

The following example illustrates the scheme: The display is rectangular with a diagonal length of 0.7 inches. The number of pixels is 1920*1080 (the number of pixels on the long side * the number of pixels on the wide side). The size of the microlens array needs to be no smaller than the microdisplay. Anything that meets this condition can be applied to this example. The size used in this example is 160mm*80mm, the diameter of a single microlens is 1mm, and the focal length is 4mm.

The light field parameters are as follows:

The distance r1=3mm from the microlens array to the microdisplay. The distances from the microlens array to the six depth planes of the reconstructed optical image are specified as L1=200mm, L2=500mm, L3=800mm, L4=1000mm, L5=1500mm, L6=2000mm.

Define the horizontal coordinate of the display pixel as i, the vertical coordinate as j, and the coordinate of the first pixel in the upper left corner of the display as i=1, j=1. The six depth planes specified for input are LR=200mm, 500mm, 800mm, 1000mm, 1500mm, and 2000mm. Firstly, the spatial information preprocessing process is carried out. According to formula (1), the sampling frequency of the light field corresponding to each depth plane is calculated, which are fR=360*203, 346*195, 343*193, 343*193, 341*192, 339*191. Use this frequency to render the target. The image is down-sampled to obtain texture map 1; according to the geometric relationship between the microdisplay-lens-reconstructed virtual plane in the integrated light field, ray tracing is performed according to the Gaussian formula, and each image unit in the texture map 1 is calculated to correspond to Multiple pixel
position information in the display is stored as a matrix, namely index matrix 1; the above process is repeated to traverse the sub-pixels of each depth plane, update and finally obtain a complete index matrix 1. Then the process of real-time processing of chrominance information is carried out. According to the depth information contained in the input image, by calling the index matrix 1, a corresponding matrix corresponding to the specific spatial position information of the image, that is, the index matrix 2 is generated. Traverse all input image units, map the chrominance and luminance information one by one, and get a complete depth EIA map. Combine each depth EIA to get the final output image.

![Fig 1. The comparison of rendered picture and EIA. a) the rendered picture, which will be saw by users. b) the EIA generated by proposed algorithm](image)

**III. References**

1. M. Martínez-Corral and B. Javidi, “Fundamentals of 3D imaging and displays: A tutorial on integral imaging, light-field, and plenoptic systems,” Adv. Opt. Photonics 10(3), 512-566 (2018).

2. H. Hua, “Enabling focus cues in head-mounted displays,” Proc. IEEE 105(5), 805-824 (2017).

3. P.-Y. Chou, J.-Y. Wu, S.-H. Huang, C.-P. Wang, Z. Qin, C.-T. Huang, P.-Y. Hsieh, H.-H. Lee, T.-H. Lin, and Y.-P. Huang, “Hybrid light field head-mounted display using time-multiplexed liquid crystal lens array for resolution enhancement,” Opt. Express 27(2), 1164-1177 (2019).