Design and Implementation of a Fast Integral Image Rendering Method

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Abstract. The computer-generated integral imaging system is a way of showing stereoscopic displays that allows users to see 3D images without wearing any special glasses. In the integral imaging system, the 3D object information is stored as elemental images, which are generated by the image mapping method. This paper reviews the previous image mapping methods, such as PRR (Point Retracing Rendering), MVR (Multi-Viewpoint Rendering), and PGR (Parallel Group Rendering). Then, it explains a new image mapping method called VVR, which shows better performance while generating similar pictures as in MVR. Finally it mentions process of making the integral imaging system, and analyzes performance. Then, it discusses some research directions for the future improvement.

1 Introduction

Virtual Reality (VR) is an interactive multimedia system that provides realistic information visuals and interactivity to users [1]. In most VR systems, stereoscopic displaying method is mostly used in these days because it can be easily implemented and shows good enough 3D effect than others. However, stereoscopic displays have some drawbacks. For example, it dose not provide the continuous viewpoint. In other words, it only gives the depth of image and solidity, but does not provide any volumetric information. Also, users of stereoscopic imaging systems should wear special glasses to see the three-dimensional images.

Autostereoscopic displays have been improved to overcome the typical drawbacks of stereoscopic displays by developing and employing new methods, such as multi-view binocular, volumetric display, and holography [2]. The integral imaging system is one of the most promising autostereoscopic system because it can provide the full color image and both vertical and horizontal parallaxes without putting any special devices on the observers [3]. Moreover, it provides the continuous viewpoint, volumetric information, to users.

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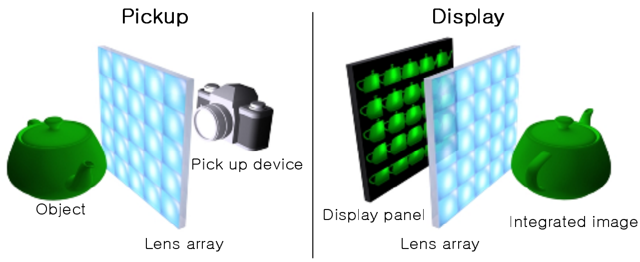

Fig. 1. The concept of the Computer Generated (CG) integral imaging system

Fig. 1 presents how the integral imaging system works. As the picture shows, the integral imaging system consists of a pickup and display parts [4]. The pickup part is implemented with the lens array and a pickup device like CCD camera; then, the system captures and stores the three-dimensional information about 3D objects as a set of two-dimensional elemental image. In the display part, the integrated image is shown to users through the lens array; then, users would be able to see the 3D object composed out of the elemental images. Instead of using a real lens array and CCD camera, the pickup part can be replaced with the computer rendering methods, which is often referred as CG (computer generated) image mapping. In this paper, we propose a fast image mapping algorithm called VVR (Viewpoint Vector Rendering). First, this paper explains several previous image mapping methods. Then, it describes the concept, design and implementation of VVR. It also presents the analysis of comparison between VVR with MVR. Finally, future directions of this research will be discussed.

2 Previous Image Mapping Algorithms

In the traditional CG integral imaging system, a set of elemental images is drawn pixel by pixel by mapping every point of the 3D object to the elemental images. This method, called PRR (Point Retracing Rendering), is widely used due to its simplicity, but is too slow to be used for real-time graphics applications [5]. The reconstruction process of the 3D integrated image takes longer and longer as the size of the object gets bigger or the number of objects is increased.

A couple of new image mapping methods have been developed to overcome the deficiency of the PRR algorithm, such as Multiple Viewpoint Rendering (MVR) [6] and Parallel Group Rendering (PGR) [7]. MVR imitates the real pickup process of the integral system by using 3D computer graphics technologies. In MVR, elemental images are generated by capturing virtual objects in a 3D space using a virtual camera. The virtual camera is moved by the elemental lens pitch the same as the real CCD camera of the integral imaging system. The advantage of MVR is that it can construct the correct elemental images by following a simple pickup algorithm. It can also use 3D models without any conversion and is not affected by the size of the virtual objects unlike PRR. However, the processing time of generating elemental images takes longer and longer as the number of lenses in the lens array gets increased since it needs to take pictures and renders for each lens of the lens array.

PGR is an algorithm that is designed to overcome the slower performance of other algorithms. In PGR, elemental images are obtained from the imaginary scenes that are observed in a certain direction, which we call the directional scenes. Then, the elemental images are assembled from the pixels of the directional scenes. In PGR, the number of directional scenes is the same as that of the pixels in the elemental lens area, and its directions are corresponded with the viewing vectors from each pixel to the center of the elemental lens. One of the advantages of this method is that the number of elemental lenses does not affect the performance. However, PGR only supports the focused mode, which can show the maximum image depth, while the resolution of the reconstructed images is degraded.

3 Design and Implementation of Viewpoint Vector Rendering

In this paper, a new image mapping algorithm called VVR is proposed, which is designed with real-time graphics in mind. VVR's construction process of elemental images is several times faster than MVR, while the quality of the elemental images is competitive to the images generated by MVR. Moreover, the image mapping process of VVR is not degraded as in MVR even when the number of elemental lenses is increased.

3.1 Viewpoint Vector Rendering

VVR method is similar to PGR in the way that VVR utilizes the directional scenes and is not affected much when the number of elemental lenses gets increased. However, unlike PGR, which can only be used in the focused mode constructing the integrated images around the lens array, VVR can be used in the focused, real, and virtual mode. Real mode in the integral imaging system means that the integral images are viewable in front of the lens array because the focal length of the lenses is shorter than the length between the display device and the lens array. Virtual mode constructs the integral image behind the lens array because the focal length is longer than the distance between the display and the lens array. As directional scenes are taken in bigger chunks and processed to fit into the smaller elemental images, it requires a little overhead of image processing. However, it is still a few times faster than MVR even if the image processing time is counted when the number of lenses is over certain threshold, which is pretty small and negligible for most integral imaging systems.

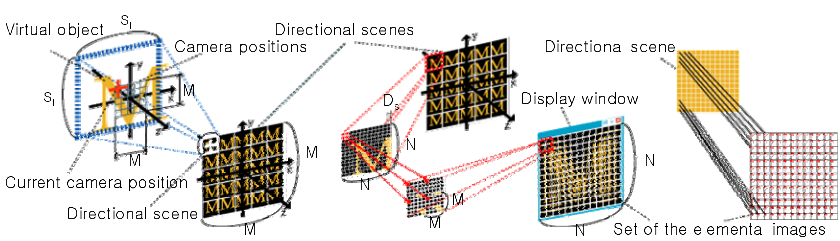

Fig. 2. The concept of the CG integral imaging system with VVR

With its faster construction of elemental images and versatility of supporting various stereoscopic modes, VVR shows advantages when it is used for real-time computer graphics than other methods.

Fig. 2 shows VVR process, which creates the set of elemental images with magnification (M) value of 5 (i.e., the number of viewpoint vectors is 5x5), and the number of elemental lenses (N) is 13. The left picture of Fig. 2 shows the pick-up process of the directional scenes, and the center image represents the displaying process. The pick-up part of VVR image mapping process is accomplished by obtaining 5x5 directional scenes. Then, each directional scene is split into 13x13 (169 in total) image segments, which is are distributed to a section of the 13x13 elemental images (see the rightmost picture of Fig. 2). When this process is iterated 25 times for 5x5 directional scenes, the final set of 13x13 elemental images are finally composed and displayed to show the integrated images.

3.2 Design and Evaluation of VVR

VVR integral imaging system is implemented using C++ and OpenGL. Fig. 3 shows the architecture of the system. As shown in the picture, VVR integral imaging system is composed of several sub-components, such as control, object, rendering, image mapping and display systems. The control system initializes some required factors for the system and manages the system to run. When it gets started, the system reads several input values of factors, such as N, M, and so on, from a configuration file. Then, it calculates other factors, such as camera positions, the size of a directional scene, the field of view value for the virtual camera, and so on. It also constructs other sub-components of the system and runs the main loop. The object system loads and manages 3D model data to be rendered by the integral imaging system. The rendering system utilizes OpenGL 3D graphics library to generate the directional scenes. It controls the virtual camera by calculating the absolute positions where the camera must be located and take a directional scene of the 3D world. The rendering system creates an image file for each directional scene, which is then manipulated in the

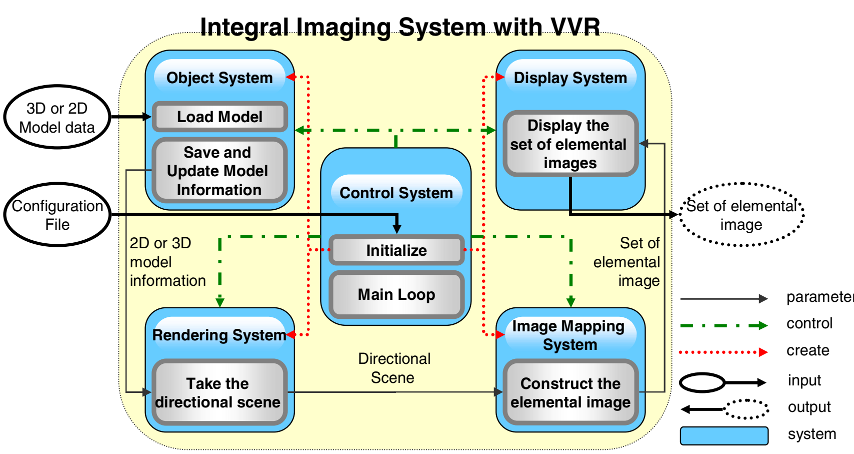

Fig. 3. Architecture of the CG integral imaging system with VVR

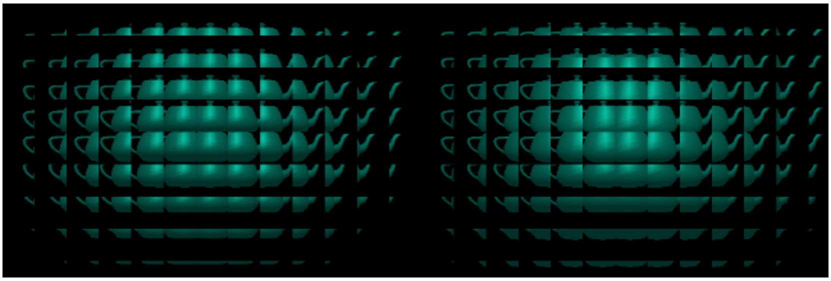

Fig. 4. Elemental images of a 3D teapot created using VVR (left) and MVR (right)

image mapping system. The image mapping system processes the slices and replacements of directional scenes, which basically assemble the final set of elemental images. The completed elemental images are then passed to the display system, which draws the images on the screen. When users see the image on the screen through the lens array, users would be able to see the 3D view.

VVR image mapping method is evaluated from two different directions. First, we tried to compare the quality of elemental images generated from both VVR and MVR methods by using the PSNR (Peak Signal to Noise Ratio) test. PSNR is widely used to find out similarity between two images; in general, if the value of PSNR is over 40dB, both images are considered to be almost identical. Fig. 4 shows a set of elemental images generated by VVR and MVR, whose PSNR value was around 50. Some more objects including 2D image planes placed in a 3D world and 3D objects have been examined with PSNR tests and found that the quality of the elemental images was generated by VVR and MVR methods are almost negligible (see Table 1).

Table 1. Ths PSNR of elemental image constructed in VVR and the MVR

MVR vs. VVR	2D Font	2D Image	3D Font	3D Cow	3D Teapot
PSNR	143.84	120.95	75.09	61.93	52.99

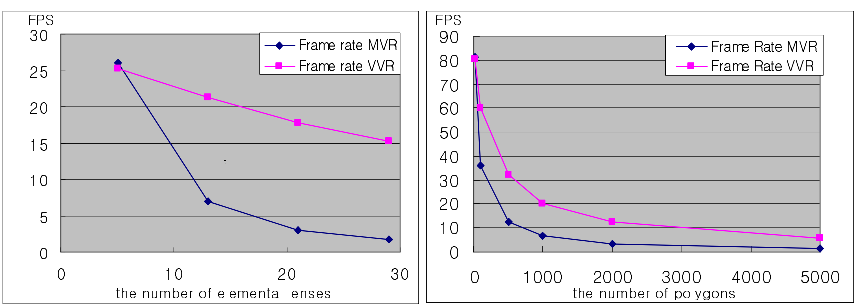

Fig. 5. FPS (Frames per seconds) of MVR and VVR

The performance of the construction process of elemental images was also evaluated. To examine the performance, the relationships between the frame rate and the number of lenses and the number of polygons, respectively, were measured for both MVR and VVR. As shown in Fig. 5, when 13x13 lens array (169 lenses in total) was used, VVR showed about 1.5~5 times faster frame rate than MVR. The picture also shows that, in overall, VVR shows better performance than MVR regardless of the number of the lenses or the complexity of the 3D models get increased.

4 Conclusion and Future Work

VVR algorithm is a new image mapping algorithm that should be more suitable for real-time graphics applications. Unlike PRR or MVR, VVR usually shows better performance in most cases and is not affected much by the number of lenses or the size of the 3D objects much, while the quality of elemental images are almost identical. Compared to PGR, which could only show the elemental images in the focused mode, VVR can show 3D integral images in either focused or real mode.

As Table 1 shows, when 2D objects (planes) are used with the new algorithm, PSNR values are pretty high, whereas the results get decreased with 3D objects. For the future research, we will try to improve VVR algorithm to get better quality of images by improving the VVR algorithm. We also have plans to increase the frame rate more so that the new method can be used in the interactive environments, such as game or virtual reality worlds.

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