Ray-Space Transmission System with Real-Time Acquisition and Display

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Abstract - Ray-Space is a novel representation of 3-D scenes, which focuses on "Rays" flying in 3-D space. We report a full-chain system of real-time acquisition, transmission, and display of Ray-Space as the ultimate 3-D visual communications.

I. INTRODUCTION

Ray-Space [1, 2] is one of the representation forms of 3-D scenes, which focuses on "Rays" flying in 3-D space. It is defined as shown in Fig. 1, where rays are represented by four parameters: a position (x, y) at which a ray passes through a reference plane (Z=0 in Fig. 1) and the ray's direction (θ, φ). In the Ray-Space concept, an acquisition of a view image is a process to sample and record ray data that pass through the camera aperture. The recorded rays correspond to 2-D subspace of the whole Ray-Space. The display of a view image, on the other hand, is a process to "cut" the Ray-Space data and extract a cross section image. Thus, Ray-Space includes all the visual information of the 3-D scene, and therefore, a full chain of real-time acquisition, transmission, and display of Ray-Space is the ultimate 3-D visual communication form.

The Ray-Space concept is essentially the same idea as "Light field / Lumigraph" [3], which have been widely known as a photo-realistic image generating method in computer graphics field. However, these researches are focusing on "Rendering", not communication, because of the difficulty of acquisition of dynamic Ray-Space. In our previous works, we proposed an Free-viewpoint TeleVision (FTV) system [4, 5] based on Ray-Space method. In FTV system, acquisition of dynamic Ray-Space is realized by a combination of multi-camera capturing and real-time interpolation. Although this system works fairly well, Ray-Space interpolation is inherently hampered by ill-posed corresponding problem.

This paper introduces our project which aims at real-time acquisition of raw Ray-Space data, transmission and display system.

II. ACQUISITION OF RAY-SPACE

One of the conventional approaches to acquire dynamic Ray-Space is to use a large number of camera arrays [6]. However, this method essentially needs interpolation of Ray-Space because the density of the acquired Ray-Space is too low to render an arbitrary view image. To overcome this, we developed a new acquisition system which consists of a high-speed camera, an optical imaging system, and optical scanning system [5]. The optical imaging system consists of a double parabolic mirror and the scanning optics consists of a galvanometer mirror. The double parabolic mirror works as an imaging optics that produces a real image of an object. The galvanometer mirror reflects the object's real image to the high-speed camera. When we scan the angle of the galvanometer mirror, the object can be observed from various directions. So, scanning the galvanometer mirror at a very high speed in synchronization with high-speed camera shutter enables us to capture dense Ray-Space in video rate.

Fig. 2 shows our real-time acquisition system. The high speed camera can capture up to 256x256 resolution images at 10,000 frames per second. This number corresponds to about 300 multiview image-capturing with the viewing angle 55 degree.

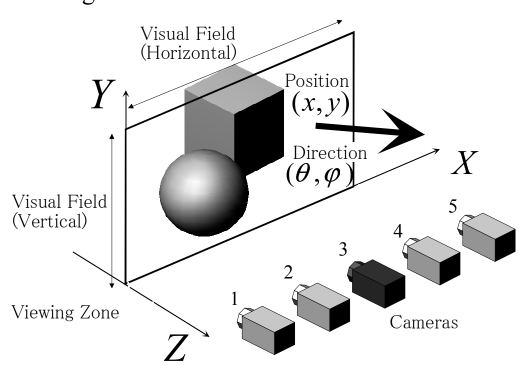

Fig. 1. Definition of Ray-Space [1, 2].

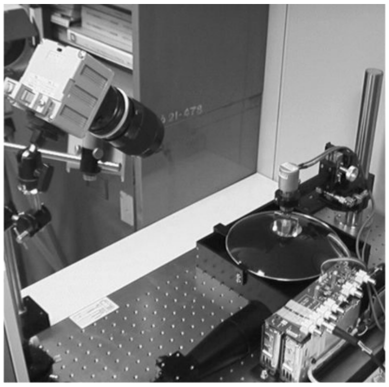

Fig. 2. Real-time Ray-Space acquisition system [5].

Fig. 3. Cylindrical 3-D display: “Seelinder [9].”

III. TRANSMISSION OF RAY-SPACE

Ray-Space requires a huge amount of data and compression is necessary for transmission and storing. One key idea of dynamic Ray-Space compression is to exploit large redundancy in both temporal and spatial directions. In MPEG (Moving Picture Experts Group), Multiview Video Coding (MVC) activity is in progress [7, 8]. The approach used in MVC is to reduce redundancy using inter-frame prediction called motion / disparity compensation, which is an extension of a new video coding standard H.264/AVC (Advanced Video Coding). Although this seems to be a good approach for Ray-Space coding, it requires high computation costs, and therefore, is not suitable to our real-time transmission system. In our first experimental system, direct transmission was adopted without compression. Development of efficient and fast compression algorithm and its implementation are our next steps.

IV. DISPLAY OF RAY-SPACE

Today, there are many kinds of 3-D displays under development, which include stereo displays, multi-view displays, autostereoscopic displays, holographic displays and so forth. Among them, ray-reproducing type 3-D displays can be seen as Ray-Space display system. Various types of such display systems are proposed using e.g. Integral Photography, parallax barrier, and pinhole arrays. An example of such a novel display is shown in Fig. 3. It is a cylindrical 3-D display called “Seelinder [9].” It consists of synchronized rotating LEDs and slits, and is able to control the rays emitting from the cylinder very precisely. Ray-Space around the cylinder is reproduced by this precise mechanism. It can reconstruct rays from the cylinder that are equivalent for 360 views in 30 fps. Thus, observers can view autostereoscopic 3-D video images from any horizontal directions.

V. CONCLUSION AND FUTURE WORK

We introduced a real-time Ray-Space transmission system based on real-time capturing, transmission, and display. This type of “Ray-Space Camera and Display” is a key technology for the next generation 3-D visual communications. The bottleneck of Ray-Space camera and display lies on the high-resolution devices for both acquisition and display. We solved this problem by introducing time-multiplexing techniques. Compression of huge amount of dynamic Ray-Space data is also an important research topic beyond multi-view image coding. Our future work is to conduct a real-time transmission experiment between remote sites.

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