An Interactive Visualization of High Frequency Electromagnetic Wave Propagation on the CAVE

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Abstract: In this paper, we propose an interactive visualization system of high frequency electromagnetic wave propagation on the CAVE. In order to display the propagation on the CAVE with both of necessary precision and easy manipulation, a tree data structure is introduced into a huge amount of volume data, which is generated by a beam based tracing technique [1]. By implementation of the proposed method with OpenGL and CAVElib, one can view and operate the propagation immersively at any viewpoints.

1. Introduction

A base station antenna arrangement problem in urban space with many obstacles is an important subject for mobile communications systems such as a wireless LAN, personal handyphone system (PHS), etc. In order to visualize high frequency electromagnetic wave propagation from an antenna, we proposed a beam based tracing method with adaptive subdivision technique [1]-[2]. In this method, tracing beams is replaced by doing sets of rays. Each beam consists of three rays. A beam is subdivided if its rays are reflected and/or refracted on different objects. After generating rays and beams, volume data of propagation is calculated from the beams and users can view the propagation at any viewpoints by using a certain volume rendering technique. Users can understand the situation more easily if the method is applied on the CAVE. However, the volume data of propagation is so huge that interactive manipulation is difficult. Additionally, the high frequency wave propagation may cause changes in an inch. In order to display the propagation on the CAVE with both of necessary precision and easy manipulation, we introduce a tree data structure into volume data. The proposed method can achieve an immersive visualization on the CAVE with low computational cost and suitable precision.

2. A Tree Data Structure of Electromagnetic Wave Propagation for Visualization on the CAVE

The proposed method consists of following three steps.

Step 1: Generate beams and volume data by tracing rays from an antenna.

Step 2: Define a tree data structure of volume data and visualize propagation on the CAVE.

Step 3: Revisualize the propagation according to the data structure in response to users' request.

Each step is described in the following subsections.

2.1 Generation of Beams and Volume Data [1]-[2]

Beam based tracing techniques [3] are useful for detection of high frequency electromagnetic wave propagation, since the propagation plays such as light. In order to generate beams representing the propagation efficiently, we define a beam as (a) a triangular pyramid or (b) a truncated triangular pyramid [1]. Both are formulated by three rays, which trace the propagation, respectively (see Figure 1). According to reflections and/or refractions new rays and beams are defined. When there are objects (e.g., building and ground) within a beam, it is subdivided until it does not contain any objects recursively [3].

A set of volume data (electric power) of propagation is calculated from these beams. In the first place a set of voxels is defined, which are small enough to represent a situation of the propagation. In the second place electric power is calculated at each voxel by identifying the beams where this voxel exists [1].

(a) rays from an antenna (b) reflected/refracted rays at an object

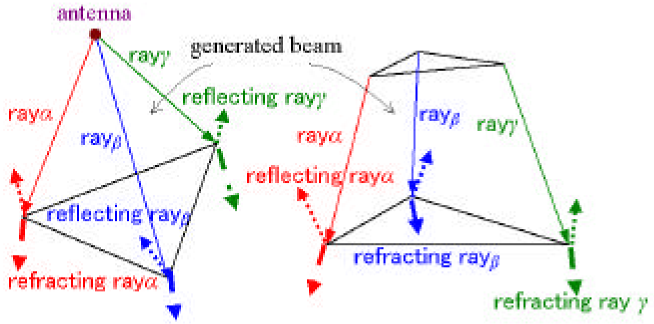

Figure1: Definition of a beam by a set of three neighbor rays

2.2 Definition of a Tree Data Structure and Visualization

Since we often consider propagation with electric power varying in a few centimeters inside of an urban space, which is at least 100 cubic meters, the number of voxels becomes huge. In order to enable smooth visualization on the CAVE, we need to reduce the visualized information. In this paper, we define a tree data structure of cubes representing the propagation. Each cube has voxels at each vertex and may contain some smaller (lower level) cubes within it. Interpolating volume data at its vertices, we render each cube using OpenGL and CAVElib. A cube is eliminated if it has less electric power (volume data) than a given threshold. Since only the top level of the cubes is defined and used at initial visualization in the proposed method, users firstly can view an approximated image from far.

2.3 Revisualization According to the Tree Data Structure

As users close to the object space, smaller (lower level) cubes are used, and bigger (upper level) ones take place when they steer away from there. Therefore the tree data structure of cubes is updated in response to users' request (moving or zooming). Cubes are eliminated at each level if their electric power is less than a given threshold (see Figure 2). The CAVE revisualizes the propagation with suitable precision using proper size and number of cubes.

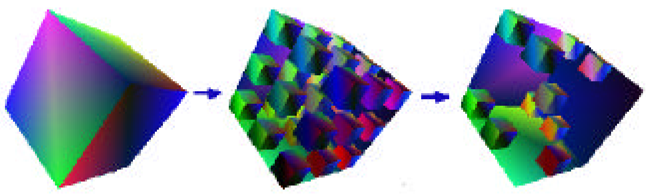

Figure 2: A tree data structure for visualization on the CAVE

3. Conclusion

In this paper, we proposed an interactive visualization system of high frequency electromagnetic wave propagation on the CAVE. One can understand the propagation situation more easily. Also, an interactive manipulation can be implemented according to users' request.

In a future research, a higher efficiency of generating beams and volume data, combining with geometric information systems (GIS), and user-friendly interface are to be considered.

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