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AN INTEGRATED FRAMEWORK FOR EFFICIENT WIRELESS COVERAGE MAPPING USING RAY TRACING ACCELERATION

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ABSTRACT

Evaluation of channel properties is one of the most important aspects in wireless communications. Ray tracing simulations have been widely used to estimate channel characteristics. In this poster, we put together many aspects of ray tracing techniques and signal estimation methods to build a coverage map. Acceleration structures for ray tracing are created to drastically reduce the computational time of the traversal of the ray-primitive intersections. Moreover, electromagnetic and wireless communications theories are studied to accurately estimate signal strength at an arbitrary point in the predefined area of the coverage map.

1 INTRODUCTION

Even though measurement campaigns provide valuable and accurate channel information, they require a tremendous effort and time. Alternatively, ray tracing simulations offers fast and reasonably accurate estimates of channel coefficients. Ray tracing models electromagnetic waves as discrete propagating rays going from a transmitter to the surrounding environment. Each ray experiences reflection, diffraction, and scattering depending on the properties of the obstruction's materials, environments, and characteristics of antennas. With those physical phenomena, wireless channels can be estimated with high accuracy.

2 METHODOLOGY

Accelerated Structure for Ray Tracing – Bounding Volume Hierarchy (BVH): Generally, a simulation scene is a complex geometry that comprises many objects. Each object consists of thousands of primitives, such as triangles. This large number of primitives drastically increases the time complexity of the ray tracing method. Among subdividing methods, bounding volume hierarchy (BVH) has gained popularity in the Computer Graphics community due to its effectiveness. BVH is a tree structure for an object that divides the object's primitives into nodes. It recursively divides primitives into two subgroups depending on the probability that a ray-group hit can occur. This process repeats until a leaf node is encountered based on certain criteria. With this accelerated structure, the ray-primitive intersection time complexity reduces from O(N) to O(log(N)).

Monte Carlo Approximation for Coverage Map: We make some reasonable assumptions for our coverage map program. First of all, we place our transmitter at a high altitude position to reduce obstruction. Secondly, the altitude of the coverage map plane is 1.5 meters higher than the ground. After placing a transmitter in a given scene, it generates millions of rays, whose directions are sampled based on the Fibonacci lattice. Each ray continuously bounces around the screen until reaching a predefined maximum reflections. If a ray intersects the coverage map plane, channel information are recorded for that intersection.

Each intersection record is put in a corresponding cell, which is a rectangle area after partitioning the screen into small units. Signal strength of a cell is estimated using the following Monte Carlo approximation:

$$\hat{b}_{i,j}^{ref} = \frac{4\pi}{N|C|} \sum_{n=1}^{N} \left| h\big(s(\omega_n)\big) \right|^2 * \frac{r(\omega_n)^2}{\left|\cos\big(\alpha(\omega_n)\big)\right|} 1_{s(\omega_n) \in C_{i,j}}$$

Where:

$\left|h\big(s(\omega_n)\big)\right|$: amplitude of the path coefficients

$s(\omega_n)$: the point where the path with direction of departure ω_n intersects the coverage map

$r(\omega_n)^2$: the length of the path with direction of departure ω_n

$\alpha(\omega_n)$: the angle between the coverage map normal and the direction of arrival of the path with direction of departure ω_n

$1_{s(\omega_n) \in C_{i,j}}$: the function that takes as value one if $s(\omega_n)$ in the cell $C_{i,j}$ and zero otherwise

3 INITIAL RESULTS AND FUTURE IMPROVEMENTS

Initial Results: A Simple Coverage Map using Monte Carlo Approximation: At the current state, the coverage map is generate using Friss free space path loss equation. The results of the coverage map for our model is presented in Figure 1.

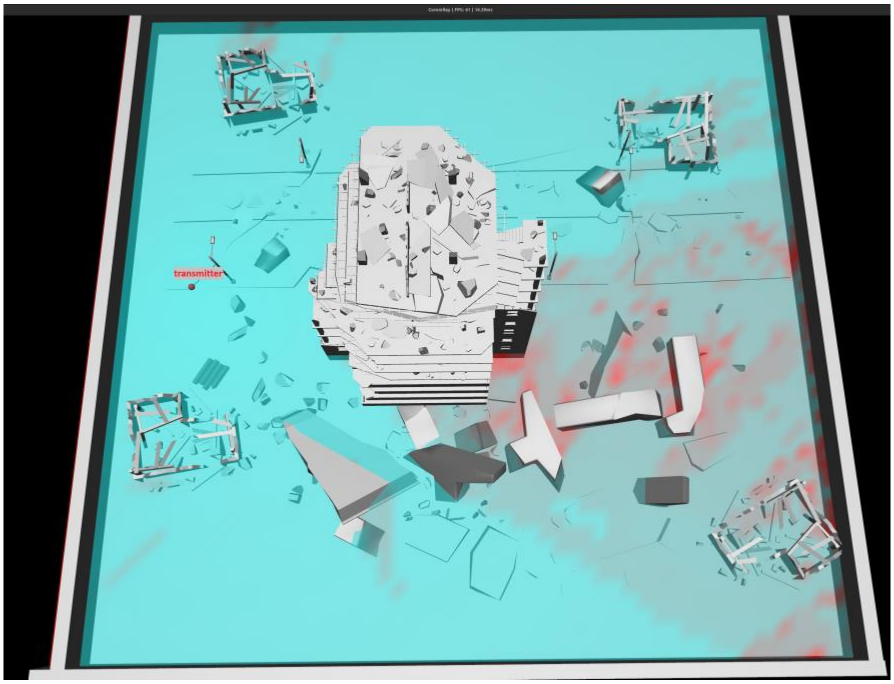

Figure1: Coverage Map is generated using the Friss free space path loss

Future Improvement: GPU Acceleration for Ray Tracing: At the current state, after optimization and applying multithreading in C++, shooting six millions rays, with the maximum reflection of 20, into the screen takes around 1 seconds to complete generating the coverage map. It is anticipated that with GPUs, it would significantly improve the speed of ray tracing.

REFERENCES

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