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Ray Tracing for Light and Radio Wave Simulations

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Summary

Being able to simulate the propagation of light waves and radio waves is very important in many areas of research, industry as well as the public sector. Both the visible light and radio waves share properties that seem wave-like, such as a wavelength or frequency, but at the same time they also appear particle like. Both kinds of waves are made up from the same particles, photons. For both high frequency radiation and visible light, certain basic optical laws do apply that can be used in the modeling of a simulation. In this thesis, we concentrate on methods using geometrical optics to simulate the propagation of visible light and radio waves.

We present two new propagation simulation algorithms based on the extension and adaptation of recent techniques for global illumination simulation. By combining and improving these highly efficient algorithms from the field of Computer Graphics, it is possible to build a fast and flexible utility to be used for wireless network simulation. Instead of the wave nature of EM radiation we rather use the particle nature of waves to compute a discrete sampling of the volumetric electromagnetic field by tracing either individual rays or whole beams of photons through the scene.

The ray tracing process results in a data structure called the Photon Path Map. This is then used to estimate the field density at arbitrary points in space. The algorithm can be applied to three dimensional indoor as well as outdoor scenarios without changes. The beam tracing approach is more suitable for outdoor scenarios and produces results much faster, since we simplify it to a 2D setting.

We also develop methods to adapt the simulation parameters to real measurements and compare the accuracy of the presented algorithms. Getting the model parameters right is important for the simulation results to have the desired accuracy. Other important parameters of the propagation simulations are the antenna patterns of the transmitting and receiving antennas in a wireless link. We show how this can be implemented in a ray-tracing framework using spherical harmonic basis functions.

Having a method for predicting the illumination situation of a given 3D model, material parameters and some light sources is necessary for many applications. Games, movies, scientific visualizations, architectural planning, car design and many other areas need simulated global illumination solutions. Algorithms that solve such illumination problems tend to be computationally very expensive. Hence we will describe in this work how fast illumination updates can be computed for the simulation of diffuse, globally illuminated, animated scenes.

The simulation of the radio wave propagation is not a work that is meant to be used on its own. In the chapter about network simulations, we describe a novel way to incorporate the Photon Path Map algorithm into a network simulator, without affecting the performance of the simulator too much. Precomputations and caching are used to keep the additional computational costs low.