Efficient Ray Tracing for Radio Channel Characterization of Urban Scenarios

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Abstract — This work presents an efficient ray tracing algorithm for radio channel characterization of urban environments by the use of classes of rays. It is based on a two-dimensional image theory, which is properly modified to yield the desired three-dimensional ray trajectories.

I. Introduction

The uniform theory of diffraction (UTD) is extensively applied in the characterization of radio wave propagation throughout urban scenarios. UTD is grounded on ray tracing, used to define the optical paths from transmitter (T) to receiver (R). Ray tracing algorithms demand large computer efforts and must be extremely efficient, especially for the analysis of complex urban scenarios [1]. The algorithms are generally based on shooting-and-bouncing (SBR) or image-theory (IT) techniques [1]. Here we propose an algorithm based on the IT. The buildings of the urban environment are modeled as cylinders with finite heights and placed perpendicularly over a flat ground. Initially, these cylinders are assumed infinite and a two-dimensional (2D) algorithm traces the trajectories [2],[3]. The 2D trajectories are then converted into 3D ones. In the process, reflections from ground and the finite heights of the buildings are accounted for. It is also possible to accommodate diffractions from the top of the buildings. The adopted 2D algorithm, which is the core of the procedure, is based on [2] and [3]. But here we propose to build the complete trajectories (from T to R) from sub-trajectories of four different classes, enabling a more efficient 2D algorithm.

II. Efficient 2D Ray Tracing

Assuming a scenario like that of Fig. 1, the aim is to attain 2D optical paths from point T to R. For that, the concepts defined in [2] (i.e., radiation area, segment visibility, *quadtree*, etc.) are applied to obtain reflected and diffracted trajectories from T to R in an efficient way. The difference from traditional ray tracing techniques is that here we define four different classes of trajectories: T-R, T-D, D-D, D-R, where D represents a diffraction point at an obstacle wedge. Each class contains only reflected ray paths between the initial point (T or D) and the final one (D or R). Reflections between any two points, up to a certain pre-established number, are obtained by a uniform procedure, as the one proposed in [2] to trace paths from T to R without diffractions. Finally, the complete trajectories are obtained by properly concatenating sub-trajectories from each class. For instance, a trajectory from T to R containing two diffractions is build from the concatenation of three sub-trajectories with the sequence T-D_1, D_1-D_2, and D_2-R. Besides avoiding redundant calculations and data storage, as one can inspect from Fig. 1, the proposed algorithm also provides an extra useful feature: for each different location of R only the sub-trajectories T-R and D-R must be recalculated. So, the algorithm is suited to characterize large outdoor urban environments. Finally, the conversion from 2D to 3D trajectories can be performed as in [3].

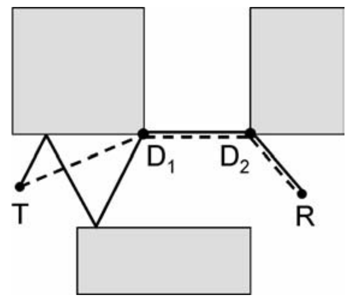

Fig. 1. Different paths from T to R sharing the same sub-trajectories D_1-D_2 and D_2-R.

III. Results

Fig. 2 shows the amount of reused sub-trajectories for a receiver located in an urban scenario composed of 80 facets (20 obstacles with rectangular cross sections), considering ray trajectories from T to R with 5 reflections and 2 diffractions, at most. In this case study, the reutilization of the T-D and D-D sub-trajectories saved about 60% of the ray-tracing time for each new receiver location. Fig. 2 also indicates that T-D and D-R sub-trajectories were the most reused ones.

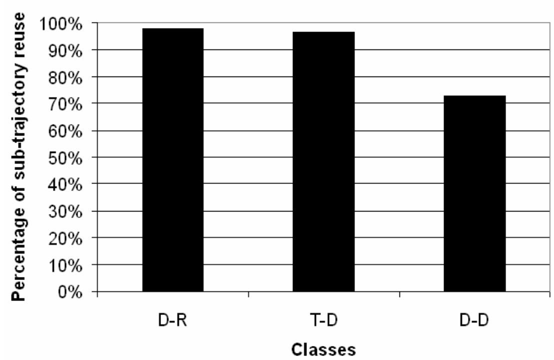

Fig. 2. Percentage of reused sub-trajectories in different classes.

IV. References

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