References

1 LOGSDON, T.: 'Understanding the NAVSTAR, GPS, GIS and IVHS' (Van Nostrand Reinhold, 1995)
2 PAPADOGLOU, N., and STIPIDIS, E.: 'Short message service link for automatic vehicle location reporting', *Electron. Lett.*, 1999, **35**, pp. 876–877
3 HOFMANN-WELLENOF, B., LICHTENEGGER, H., and COLLINS, J.: 'GPS theory and practice' (Springer-Verlag, 1994)
4 GOODMAN, D.J.: 'Wireless personal communications systems' (Addison-Wesley, 1998)

Ray tracing method for propagation models in wireless communication systems

Zhijun Zhang, Z. Yun and M.F. Iskander

A new triangular-grid ray tracing (TGRT) method is proposed. It is based on dividing the propagation region into triangles. The number of triangles is decided by the number of vertices of the structures, instead of their dimensions. For the 2D case, it can decreases the visible decision calculation to two edges for each triangle. It is shown that this method unifies the indoor and/or outdoor propagation problems and provides savings in computational time.

Introduction: Propagation prediction is very important in the design of wireless communications systems. The ray tracing method has become a vital tool for propagation prediction. This is especially true for the micro- and pico-cell cases since site specific propagation information is needed in developing these communication systems [1].

The conventional ray tracing method is based on a ray-launching and bouncing procedure which can be very inefficient if no speed-up algorithm is employed. Several schemes have been developed to accelerate the ray tracing procedure, e.g. the image method, the bounding box method and the utilisation of visibility [2, 3]. Although these methods have their own advantages, a more efficient method is needed to cope with the complex and often computationally demanding indoor or indoor/outdoor situations while maintaining good accuracy of the propagation prediction results. In this Letter we propose an efficient ray tracing method based on a triangular division of the propagation space.

TGRT method: The developed triangular-grid ray tracing (TGRT) method can be used in both 2D and 3D problems. In 2D cases, a triangular mesh is used to discretise the propagation region of interest. In 3D cases, tetrahedral or triangular cylinders may be used. We focus on the 2D case; an extension of the procedure for the 3D case is presently being developed.

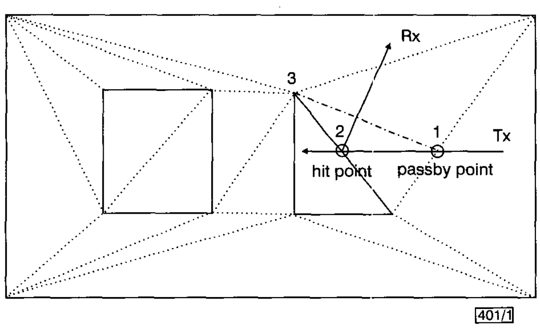

Fig. 1 *Triangular mesh layout or propagation domain*

——— walls
·········· additional grid edges

The construction of the triangular mesh is rather straightforward. The entire region of interest is enclosed by a polygon (in our case, a rectangle, see Fig. 1). Each room or building is represented by an edge defined by two points (vertices). A set of vertices is thus obtained and a triangular mesh is constructed using these vertices and satisfying the condition that each edge, except the edges of the bounding polygons, is used by only two triangles. Using this procedure, the total number of triangles, $N_{triangle}$ and the total number of edges, N_{edge}, can be uniquely determined by the number of boundary vertices, N_{bv}, and the number of all vertices N_v as follows:

$$N_{triangle} = 2(N_v - 1) - N_{bv} \quad (1)$$

$$N_{edge} = 3(N_v - 1) - N_{bv} \quad (2)$$

Eqns. 1 and 2 show the number of triangles and edges, and hence the proposed solution procedure, depends only on the number of vertices. Since it does not include a search procedure, it provides significant computational advantage.

Fig. 1 shows a triangular meshed layout for a rectangular propagation region of interest. This region includes two buildings (defined by walls), one rectangular and one triangular in shape. There are two types of edge, one is a true wall of a structure in the propagation domain, while the other is an additional grid edge. If a ray crosses a grid edge, such as point 1 in Fig. 1, it just passes by the edge and proceeds to the next one. If a ray hits a wall, such as point 2 in Fig. 1, a reflected and/or transmitted ray will be created according to the electrical properties of the wall.

It should be noted that in each triangle and with the arrival of the propagating ray to one of the edges, only two other edges need to be checked to determine which one will be hit next by the propagating ray. This decision can be made fairly easily by observing the sign of the vector multiplication between the ray's direction vector and vector from the two points defining the vertices of the edge under consideration (e.g. points 1 and 3 in Fig. 1). Because all the information about the adjacent triangles related to each edge is known, the ray can quickly go through from one triangle to another by a 'pointer-locating' method instead of requiring time consuming searching algorithms.

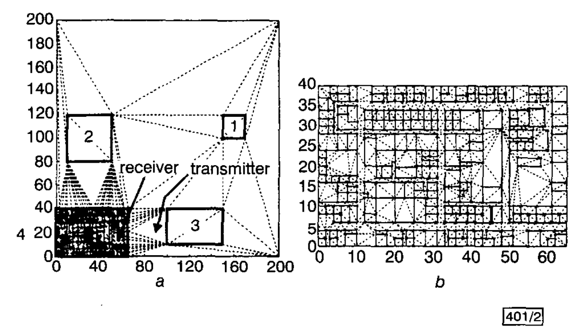

Fig. 2 *Triangular mesh layout for indoor–outdoor propagation domain and detailed triangular meshing in building 4*

a Triangular meshed layout for indoor–outdoor propagation domain
b Detailed triangular meshing in building 4
——— walls
·········· additional grid edges

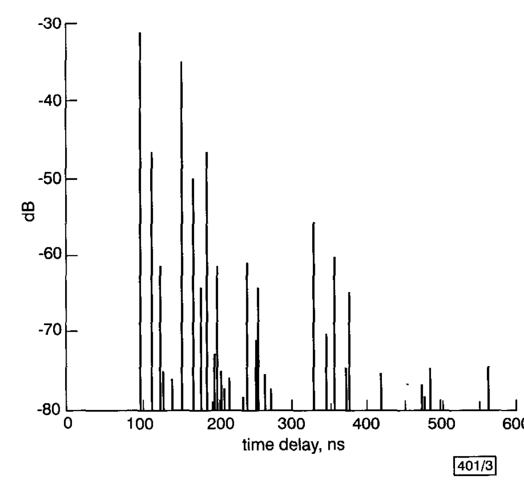

Fig. 3 *Time delay spread result for indoor–outdoor propagation in building 4*

Results: Fig. 2 shows an indoor–outdoor environment which contains four buildings emphasised by solid lines. Building 4 in the left lower corner is the building under consideration and propagation within this building is of interest. Only reflections from other building are considered, so they are simplified as blocks. The total area of the propagation domain is $200 \times 200m^2$ and the area of building 4 is $65 \times 40m^2$, which is only 6.5% of the total propagation area. The total number of triangles in the entire propagation domain is 973 and 906 triangles were placed in building 4. It can be seen that the TGRT method can adaptively adjust its grid size in different areas, so it can unify all indoor and outdoor problems and provide accurate results while maintaining high computational efficiency by placing emphasis on the regions of interest. This is clearly in addition to the computational advantages provided by the triangular and the described straightforward ray tracing procedure.

Fig. 3 shows the delay spread results (magnitude and time of arrival of various rays) for an outdoor to indoor propagation case where the transmitter and receiver were located as illustrated in Fig. 2.

Detailed comparison with other methods will require programming these methods and running them for the same geometry on the same computer. This work is presently underway and will be reported in the near future.

6 January 2000
Electronics Letters Online No: 20000345
DOI: 10.1049/el:20000345

Zhijun Zhang, Z. Yun and M.F. Iskander (*Electrical Engineering Department, University of Utah, Salt Lake City, UT 84112, USA*)

E-mail: iskander@ee.utah.edu

References

1 SEIDEL, S.Y., and RAPPAPORT, T.S.: 'Site-specific propagation prediction for wireless in-building personal communication system design', *IEEE Trans.*, 1994, **VT-43**, (4), pp. 879–891

2 CATEDRA, M.F., PEREZ DE ADANA, J., and GUTIERREZ, O.: 'Efficient ray-tracing techniques for three-dimensional analyses of propagation in mobile communications: application to picocell and microcell scenarios', *IEEE Antennas Propagat. Mag.*, 1998, **40**, (2), pp. 15–28

3 LIANG, G., and BERTONI, H.L.: 'A new approach to 3-D ray tracing for propagation prediction in cities', *IEEE Trans.*, 1998, **AP-46**, (6), pp. 853–863

Video signal transmission for IS-95 environment

A.Kh. Al-Asmari, D. Arya and S.C. Kwatra

A novel compression scheme for video sequences that is robust to fading errors in a spread spectrum environment is presented. A 3D coder has been designed in which the sequence was decomposed into spatio-temporal sub-bands and encoded using vector quantisation. Channel simulation shows good image reconstruction with a PSNR of 27dB under the worst-case channel conditions of 18dB.

Introduction: In recent work on digital image transmission over wireless channels, image transmission in the IS-54 environment has been investigated and compression rates varying from 0.125 to 0.35bit/pixel have been achieved with image quality varying from a very good coarser approximation to a near original quality image [1]. However, little work has been carried out so far into image transmission by employing the well-known antimultipath spread spectrum technique. Since the CDMA technique is gaining popularity within the cellular industry, it presents an obvious choice for this type of research work.

The use of a spread spectrum scheme elegantly resolves the two basic technical challenges of terrestrial digital cellular networks: multiple user interference and multipath propagation [2]. The first issue is resolved because each user's signal appears as white noise to all other users, which can be eliminated by digital demodulation and error-correcting decoding processes. The fading resulting from multipath propagation is mitigated due to the frequency diversity inherent in wideband systems. The multipath reflections are received as replicas of the original signal, with different delays. The delayed signals can be separated, individually demodulated, and recombined constructively using a Rake receiver [3], so that multipath propagation can actually be exploited to improve the performance of the CDMA system.

The aim of this research is to achieve bit rates of 0.25bit/pixel for video transmission, to be tested in a spread-spectrum environment. The wireless channel to be simulated for image transmission is chosen to be the CDMA-based North American digital cellular standard IS-95A.

3D decomposition of image sequence and coding: The extension of spatial filtering to three dimensions can enable us to exploit the temporal redundancy which exists between the subsequent frames of a video sequence. The proposed algorithm in this Letter uses pyramid coding for spatial decomposition. Temporal decomposition is accomplished by the use of a two-tap Haar filter, which offers the advantage of computational simplicity over the more complex methods, involved in any motion-compensation technique such as MPEG. The temporal low band is further filtered by applying the spatial 24-tap FIR filter given in [4]. Since this filter allows for a decimation factor of 4, a higher compression ratio is possible here. However, owing to the sparse nature of information in the temporal high band, this filter does not work very well with it. The five-tap Gaussian filter is used to decompose the temporal high band.

The decomposed bands are coded using vector quantisation (VQ). The neural network algorithm frequency selective competitive learning (FSCL) is used for designing the codebook for vector quantisation [5]. This algorithm is much faster than classical algorithms as they process data in parallel. In this decomposition process, most of the signal energy resides in the lower temporal/spatial frequency bands. The high temporal/low spatial frequency bands carry most of the motion information and act as a motion detector. Since the baseband contains only the slowly varying information content, its codebook vectors do not exhibit widely varying geometric patterns. Thus, a small-sized codebook is sufficient to represent all the vectors in this band. A codebook of size 64 vectors with 4 pixels each was chosen for this work. The second level in the pyramid has the high-frequency content of the decomposed temporal low band and requires a separate codebook for its coding. This codebook has been trained on data that have a widely varying edge content so that it can faithfully code data of a similar nature. The size of this codebook is 256 with dimension 4. The high temporal/low spatial band contains a small amount of the total signal energy. Nevertheless, these data are perceptually very significant as they contain most of the sharp edge and contour information as well as the fast motion aspects. The neural vector quantisation approach used for the decomposed temporal low band does not work very well for this. Instead, a perceptually efficient image coding scheme is required that can preserve the underlying edge geometries in the high frequency signals at low coding rates. The geometric VQ is adapted in this Letter where the codevectors are derived from a small set of local geometric patterns found in the high-frequency sub-bands. The high temporal/high spatial band has an extremely low energy content and the sparse information carried in it is not significant in the final image reconstruction. Therefore, it can be safely discarded.

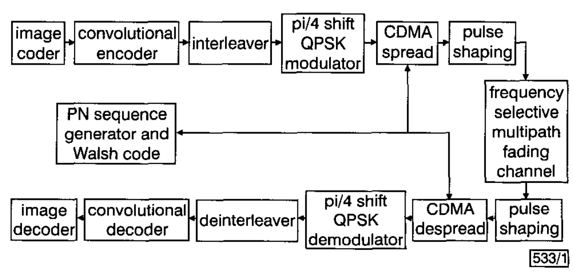

Fig. 1 *IS-95A Standard specification for transmission and reception across CDMA wireless channel*