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GLOBAL DESCRIPTIONS OF DIGITALIZED TERRAIN DATA FOR PROPAGATION STUDIES IN RURAL ENVIRONMENTS

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Abstract

Implementation of pseudospline interpolating functions for global modelling of surfaces, as defined by digitalized terrain data, is explored with a view towards its application to propagation studies in rural environments. Due to their inherent properties, pseudosplines are shown to require a reduced number of data points for proper surface representation with consequent alleviation of storage and processing time demands.

1. STATEMENT OF THE PROBLEM

Radio propagation studies aiming at the characterization of terrestrial links in rural environments are a key factor for communications systems design. In particular, adequate information on terrain profiles along paths between transmitter and receiver stations is frequently needed for proper assessment of coverage areas.

In Brasil, government agencies such as IBGE provide with topographic charts for major regions of the country containing, among others, information on iso-curve elevations which must be digitalized and processed for its efficient usage in various disciplines. To this end, a methodology for obtaining reliable altimetric information from standard cartographic maps, covering the phases of image aquisition, binarization, vectorization and elevation assessment has been developed and implemented at CETUC [1]. Customized information, such as profile characteristics along chosen azimuthal surface cuts, are then made available allowing, for example, the evaluation of propagation impairments and/or suitable locations for end terminals.

A valuable improvement on the above methodology would consist in adding the capability of full surface (analytical) descriptions as provided by global interpolating functions, even if handling very rough terrain might render their decomposition into suitable cells necessary. In this way, users might apply the various scattering techniques directly or previously undertake further discretization along preferable (many) directions according to specific needs.

Previous studies in the framework of reflector antenna synthesis and analysis evidenced the superior stability and adequacy of Pseudosplines, as compared to the implementation of more conventional series expansions, to represent highly shaped surfaces [2], which justifies investigating their applicability to the problem at hand. Specifically, it is implemented an algorithm whereby, starting from a reduced set of arbitrarily located data points (chosen from the larger imput set of terrain data), new points are progressively added where coordinate residues are larger until a pre-specified tolerance is achieved. This pseudospline unique feature of permitting local refinements amidst global interpolations thus yields a considerable reduction in the overall computational effort involved. The family of pseudosplines, obtained from the minimization of appropriate functionals, comprises a set o global interpolating functions with polynomial degrees resulting from forcing the continuity of derivatives up to a certain order. Unknown coefficients of these expansions are then obtained by point-matching at (known) data points and imposing a boundary condition whereby higher-order continuous derivatives remain finite away from each data point. Although higher-order pseudosplines yield smoother surface descriptions by making use of fewer data points distributed in less dense grids than their lower-order counterparts, at least for smooth surfaces as evidenced in connection with reflector antennas [3], lower-order ones are expected to be more adequate for rougher terrains without demanding larger data storage and shall be employed herein.

For global interpolation of a surface numerically defined by a set of N data points of coordinates (u_i, v_i, z_i), the resulting cubic (the lowest order in the family) pseudospline (CPS) expression is written as

$$z(u,v) = \sum_{i=1}^{N} a_i \, [r_i(u,v)]^3 + b_1 u + b_2 v + b_3 \qquad (1)$$

with

$$\sum_{i=1}^{N} a_i \, P_k \, (u_i, v_i) = 0, \quad k = \overline{1,3} \qquad (1a)$$

where (u,v) may stand for (x,y) or suitable direction cosines, $P_1(u,v) = u$, $P_2(u,v) = v$, $P_3(u,v) = 1$ and $r_i(u,v) = [(u-u_i)^2 + (v-v_i)^2]^{1/2}$ represents the distance, in the plane u-v, from the point where (1) is being evaluated to data points at coordinates (u_i,v_i). Coefficients $\{a_i\}_1^N$ and $\{b_j\}_1^3$ are then obtained via solution of the symmetric system of N+3 linear equations composed of boundary condition (1a) and those resulting from point-matching (1) at the N data points.

CPS implementation for a certain terrain example is next explored with a view towards establishing its adequacy and trade-offs in connection with radio propagation applications.

3. CASE STUDY

The terrain example considered herein, comprising thoroughly hilly portions as well as more sparsely distributed moderate ones, presents an adequate case study for the problem at hand. The $3{,}217 \times 5{,}462m^2$ area, as defined by iso-curve elevations from a set of 24,000 points distributed more densely in critical regions, was then interpolated by CPS starting from a reduced subset of 4,000 data points. The CPS algorithm was initialized with selected 363 points ending with 540 points, which corresponded to (rms values of) elevation residues of 16m in data points not used by the algorithm. For application in obtaining VHF/UHF coverage patterns, this was considered acceptable as revealed by the distribution of elevation residues in Fig. 1a as related to CPS-obtained iso-curve elevations and corresponding 3-D representation in Figs. 1b and 2, respectively.

4. REFERENCES

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[3] J.R. Bergmann and F.J.V. Hasselmann, "On the interpolation of reflector surfaces by psedosplines", IEE Proceedings Microwaves, Antennas and Propagation, Vol. 144, No. 1, 42-46, February 1997.

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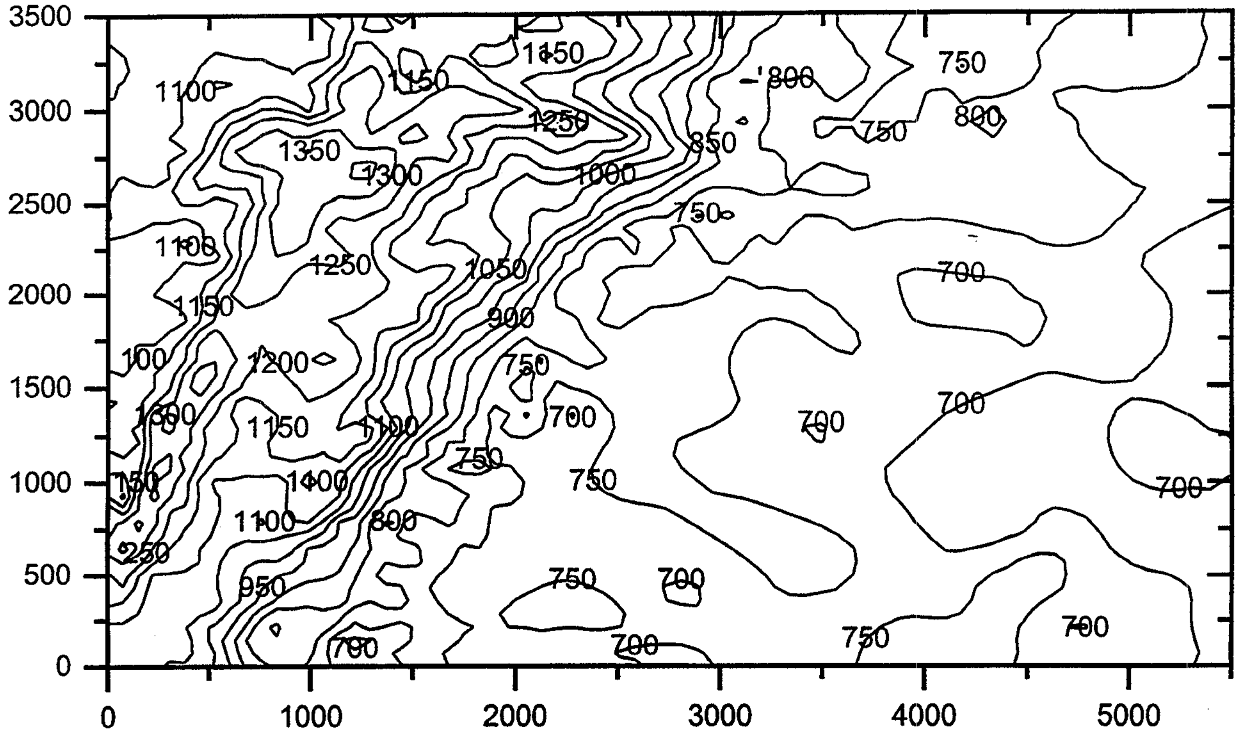

Figure 1.b - CPS-obtained iso-curve elevations

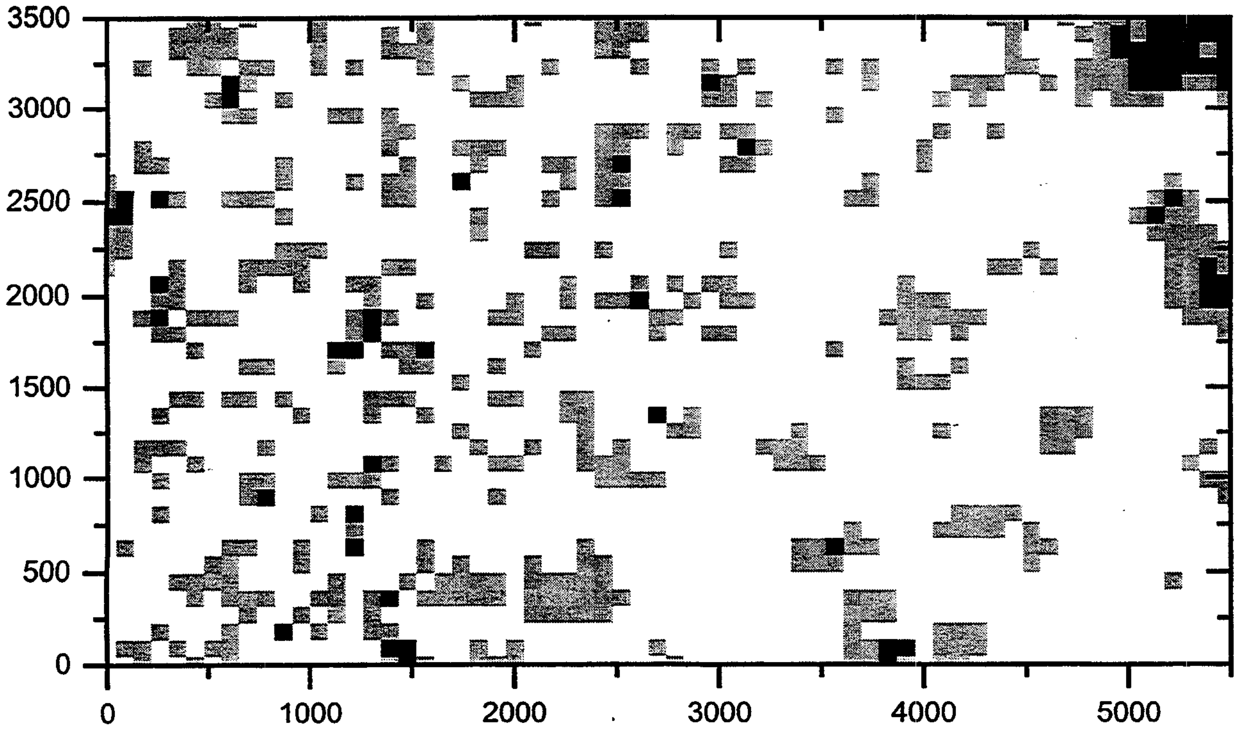

Figure 1.a - Distribution of elevation residues (m)

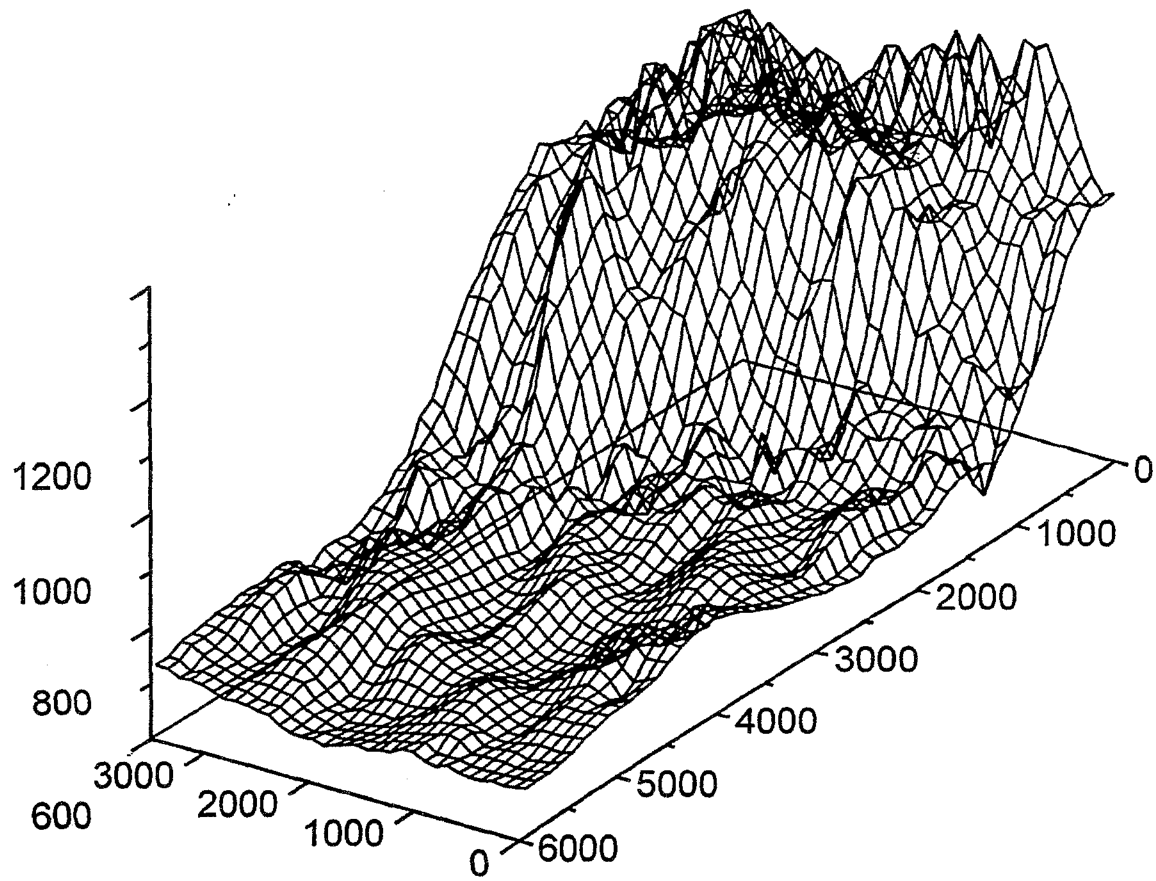

Figure 2 - CPS- obtained 3-D surface representation