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RESUMO - NOTAS / ABSTRACT - NOTES

The interpolators used for the densification of Digital Elevation Models normally do not take into account additional information known to the operator, like rivers, lakes (flat areas), or mountain ridges. They interpolate based on the control points only. The Beta-splines curves, on the other hand, have properties that enable the operator to modify the bias and the tension for each cell by assigning values to the parameters beta1 and beta2. Thus, it is possible to force the resulting three dimensional surface to acquire a desirable shape. The disadvantage is the relatively large amount of extra calculations, but with the now available faster, and cheaper microcomputers, this disadvantage can be overcome. This work tests the use of Beta-splines interpolators for DEM's running on an IBM-PC-like environment.

OBSERVAÇÕES / REMARKS

This paper will be submitted to the "International Society of Photogrammetry and Remote Sensing (ISPRS)", Tsukuba, Japan, May 15-18, 1990.

RESUMO

Os interpoladores usados para a densificação de Modelos Digitais de Elevação normalmente não levam em conta informações adicionais do conhecimento do operador, como rios, lagos (áreas planas), ou cristas de montanhas. Eles interpolam baseado apenas nos pontos de controle. As curvas Beta-splines, por outro lado, têm propriedades que permitem ao operador modificar o viés e a tensão para cada cédula, por meio de uma atribuição de valores aos parâmetros β_1 e β_2 . Então, é possível forçar a superfície tridimensional resultante a adquirir uma forma desejada. A desvantagem é o volume relativamente grande de cálculos extra necessários, mas com os mais rápidos e baratos microcomputadores já disponíveis esta desvantagem desaparece. Este trabalho testa o uso de interpoladores Beta-splines para Modelos Digitais de Elevação rodando em máquinas do tipo IBM-PC-XT.

BETA-SPLINES INTERPOLATION FOR DIGITAL ELEVATION MODELS

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Abstract

The interpolators used for the densification of Digital Elevation Models normally do not take into account additional information known to the operator, like rivers, lakes (flat areas), or mountain ridges. They interpolate based on the control points only. The Beta-spline curves, on the other hand, have properties that enable the operator to modify the bias and the tension for each cell by assigning values to the parameters β_1 and β_2 . Thus, it is possible to force the resulting three dimensional surface to acquire a desirable shape. The disadvantage is the relatively large amount of extra calculations, but with the now available faster, and cheaper microcomputers, this disadvantage can be overcome. This work tests the use of Beta-splines interpolators for DEM's running on an IBM-PC-like environment.

1. INTRODUCTION

The Institute for Space Research - INPE - developed a Geographical Information System (GIS) based on an IBM-PC-like environment (1). One of the possible operations this system performs is Digital Elevation Models (DEM) manipulations, like the change in scale and visualization from different observer positions. In order to achieve acceptable results, it is necessary to use a good interpolator. The GIS of INPE already has two interpolators available: linear, and Akima. The first one is not proper for certain applications, due to the lack of smoothness, while the other is excellent for certain cases. However when additional information about the terrain is known, like flat areas or sharp edges, the above interpolators do not perform properly. An interpolator, the Beta-spline, allows the operator to reshape the resulting surface by allotting different values for parameters β_1 and β_2 , that change the surface bias and tension, respectively, in each cell.

The Beta-spline program was developed, on C computer language, to be added to the INPE's GIS. The main objective of this work is to test a first version of this software, for the evaluation of its performance, especially with respect to the use of a microcomputer, for DEM applications.

Next section presents a brief outline of the Beta-spline interpolator, the following the results obtained with the use of this technique applied to examples, finally some conclusions are drawn, regarding microcomputer performance.

2. BETA-SPLINES

Beta-splines are generalizations of the known B-splines (2). They can be represented parametrically by:

$$Q_{ij}(\bar{u}, \bar{v}) = \sum_{i,j} V_{ij} B_{ij}(\bar{u}, \bar{v})$$

where the V 's are the control vertices, and $B_{ij}(\bar{u}, \bar{v})$ are basis functions in two independent parameters, \bar{u} and \bar{v} , that are nonzero locally, that are non-negative, and that sum to one.

Bartels et al. divide the basis function into two independent basis functions, each depending on just one of the space parameters u or v . Thus, the Beta-spline formula becomes, with $u = \bar{u} - u_i$, and $v = \bar{v} - v_i$, according to Bartels et al. (2).

$$Q_{ij}(u, v) = \sum_r \sum_s V_{i+r, j+s} b_r(u) b_s(v)$$

with r and s varying in the range $-3, \dots, 0$, for each patch (or cell). $Q_{ij}(u, v)$, the i th, j th patch is determined by 16 control vertices. The basis functions $b_r(u)$, and $b_s(v)$ have the same form and are dependent on the parameters β_1 and β_2 . It is possible to use different β_1 and β_2 for each of the functions and for each cell. The generic formulas for the b 's are:

$$b(-0)(x) = 1/d * [2u^3]$$

$$b(-1)(x) = 1/d * [2 + (6\beta_1)u + (3\beta_2 + 6(\beta_1)^2)u^2 - (2\beta_2 + 2(\beta_1)^2 + 2\beta_1 + 2)u^3]$$

$$b(-2)(x) = 1/d * [(2\beta_2 + 4(\beta_1)^2 + 4\beta_1) + (6(\beta_1)^3 - 6\beta_1)u - (3\beta_2 + 6(\beta_1)^3 + 6(\beta_1)^2)u^2 + (2\beta_2 + 2(\beta_1)^3 + 2(\beta_1)^2 + 2\beta_1)u^3]$$

$$b(-3)(x) = 1/d * [2(\beta_1)^3 - (6(\beta_1)^3)u + 6(\beta_1)^3u^2 - 2(\beta_1)^3u^3]$$

and

$$d = \beta^2 + 2(\beta_1)^3 + 4(\beta_1)^2 + 4\beta_1 + 2 \neq 0$$

If β_1 is made equal to 1 and β_2 equal to zero, the B-spline formulas are recovered.

3. RESULTS

In order to test the Beta-spline's performance, it was developed on an IBM-PC-like ambient a software to generate the surface and display it.

It was chosen a DEM from a real terrain, near São José dos Campos SP, Brazil. Six examples with different β_1 and β_2 pairs were used to demonstrate the parameters effect on the DEM. It is possible to use different parameters for each patch and each direction (u and v). However, on this work, it was not attempted to do it. It were used the same betas for the whole DEM. however, since a wide range of possible betas combinations were tried, it is hoped that it was enough to assess the Bete-splines capabilities.

Figure 1 is an interpolation with β_1 equal to one and β_2 equal to zero. This corresponds to the B-spline interpolator (2). Table 1 presents a summary of all the tested cases.

TABLE 1

Case	β_1	β_2	Figure
A	1	0	1
B	8	0	2
C	1	25	3
D	1000	10	4
E	1	8	5
F	0.0001	10	6

The parameter β_1 is responsible for the bias. One means a centered surface patch around the control vertices, while less than one means a distortion towards u and v near zero, and larger than one values a distortion towards u and v near 1. As far as β_2 , zero means that the tension is the same as in a B-spline surface, while larger values indicates that the curve passes closer to the control vertices. When β_2 is infinity, the interpolation becomes a linear interpolation, if β_1 is one (2).

Cases A, C, and E are without bias, and A and B without tension Figures 2 to 6 present the effect of the use of Beta-splines on the DEM under study.

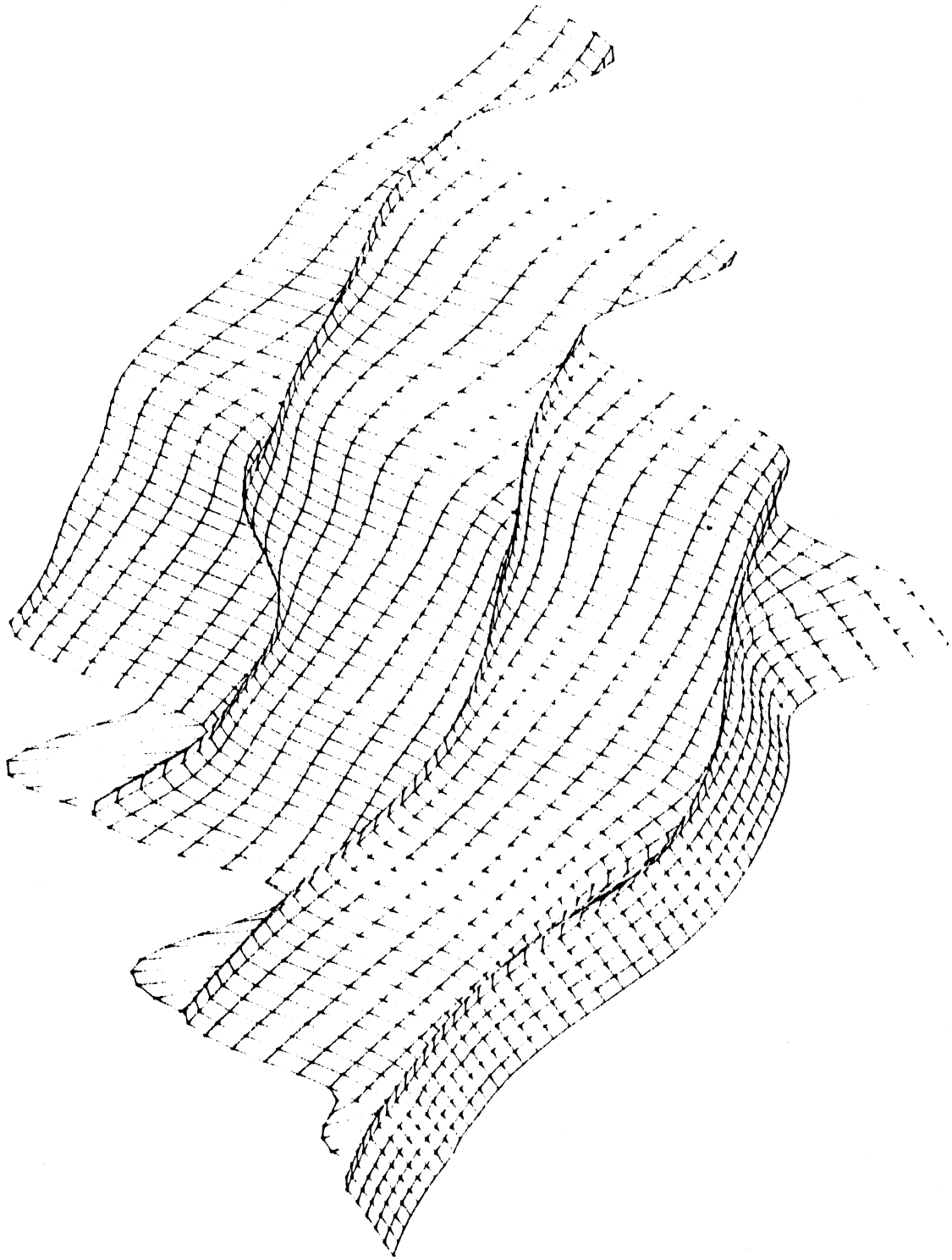


Fig. 1 - $\beta_1 = 1$; $\beta_2 = 0$



Fig. 2 - $\beta_1 = 8$; $\beta_2 = \emptyset$



Fig. 3 - $\beta_1 = 1$; $\beta_2 = 25$



Fig. 4 - $\beta_1 = 1000$; $\beta_2 = 10$

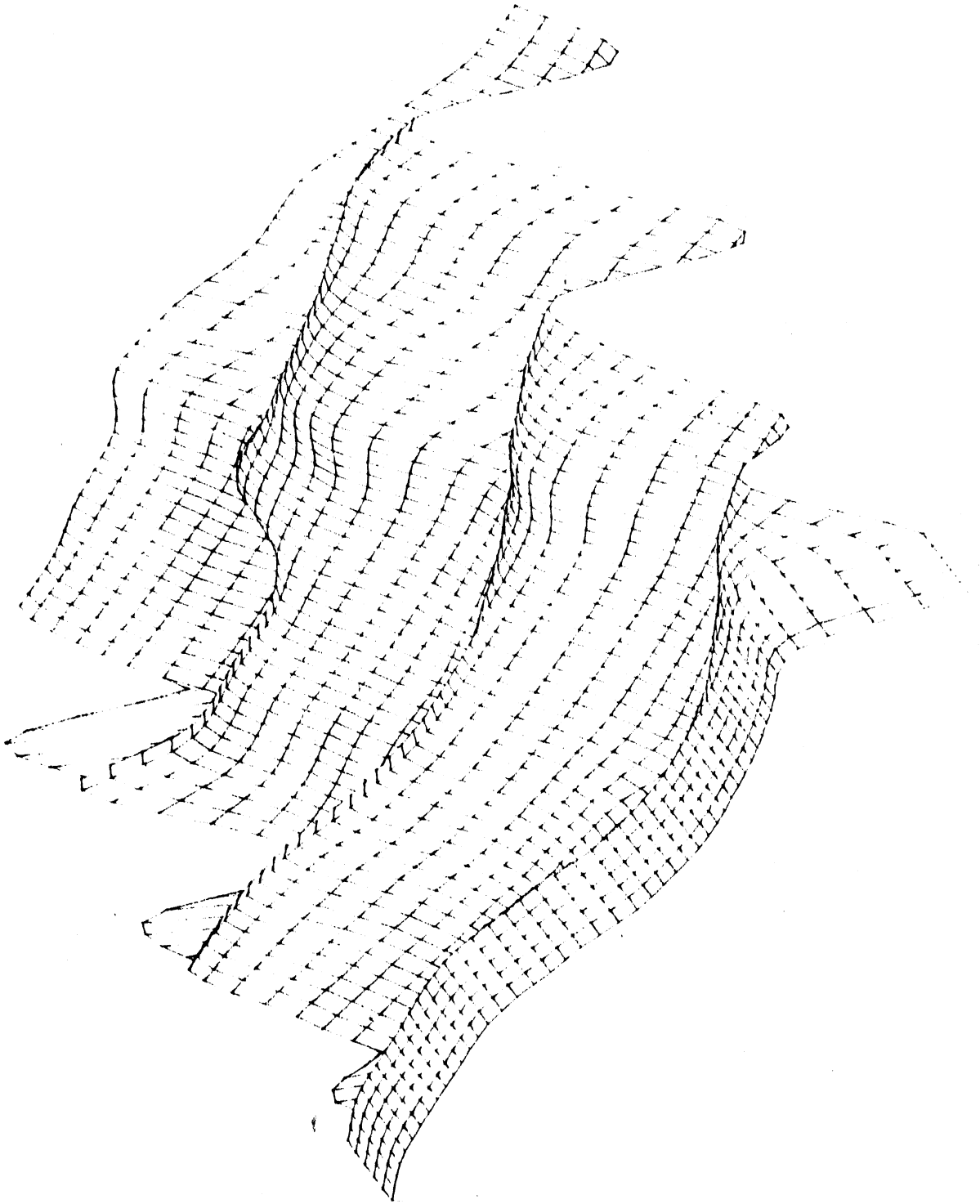


Fig. 5 - $\beta_1 = 1$; $\beta_2 = 8$



Fig. 6 - $\beta_1 0.001$; $\beta_2 = 10$

4. CONCLUSIONS

One of the main objectives of this work was to test the microcomputer behavior, since long calculations have to be performed. The hardware used for the display was the SITIM, an INPE developed image processing microcomputer based system. The calculations were made on two types of microcomputers, on an IBM-PC-XT without arithmetic coprocessor, that took 36 minutes, and on an IBM-PC-AT with arithmetic coprocessor, in which the computations for each DEM were made in 5 minutes and 40 seconds. Since the code is not optimized these times can be reduced. The plots were made with the help of the Fundação Valeparaibana de Ensino SITIM System. The authors would like also to thanks INPE and IBM Rio Scientific Center for the support, since this work is part of a joint project been run by both institutions.

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