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3D TERRAIN RECONSTRUCTION USING SCATTERED DATA SETS

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Abstract. The paper presents a scientific visualization technique using scattered data. The visualization system is based both on modules written by the authors, implementing controlled Shepard interpolation algorithm and ready-to-use VTK classes.

1. Introduction

The proposed visualization system is based both on modules written by the authors (implementing sub-sampling, re-sampling and controlled Shepard interpolation algorithm), sustaining the modeling level, and VTK classes [4], for the logical visualization and physical visualization level.

The application goal is to transform the 2D data, representing the altitude measured in some known points, non-uniform distributed, into interactive 3D maps. The structure of the output data/files should allow the Internet distribution. The main issues are the speed and accuracy of the used algorithms [7].

A file that contains the non-uniform distributed data, namely, represents the data set: the position of the nodes on a horizontal plane and the corresponding altitudes. The controlled re-sampling of the input data solves the modeling problem; in order to obtain a uniform distributed data set. The re- sampling propagates the local properties (the altitude value) towards the unknown-valued points. The propagation is implemented using the modified local Shepard interpolation. A number of constraints are necessary [5, 2, 3]. The whole process is described below.

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The uniform distributed data set is visualized using the warping of a plan, taking into account the corresponding altitude of each point [1, 6]. Artificially associated colors allow a better perception of the visualized object.

2. Re-sampling of the data set

The data set analysis shows that the input data set is non-uniform, meaning that the data is represented by unconnected nodes and their associated altitudes. In order to obtain a uniform distribution, as requested by the logical visualization level, a re-sampling of the data set is performed.

We denote by N the number of non-uniform distributed points on a plane, in a considered domain B.

$$(x_i, y_i), i = 1, \ldots, N \tag{1}$$

$$(x_i, y_i) \in B \subseteq \mathbb{R}^2 \tag{2}$$

The corresponding altitudes are given by function $f : B \to \mathbb{R}$, which associates to each point (x_i, y_i) a real value $f(x_i, y_i)$ denoted by f_i.

The visualization platform used, personal computers, and the dimension of the data set, 25500 nodes, imposed the use of a modified version of the local Shepard interpolation. The introduced constraints had as result an important speed improvement.

We denote by Φ the interpolation function $\Phi : B \to \mathbb{R}$. The Shepard interpolation function is expressed as sum of weights:

$$\Phi(x, y) = \sum_{j=1}^{N} w_j(x, y) f_j \tag{3}$$

The interpolation function has to fulfill the condition:

$$\Phi(x_i, y_i) = f_i, i = 1, \ldots, N. \tag{4}$$

Then weight function is supposed to:

$$\sum_{j=1}^{N} w_j(x,y) = 1. \tag{5}$$

$$w_j(x,y) = \begin{cases} \geq 0 & \text{for all } (x,y) \in B \\ = 1 & \text{for } (x,y) = (x_j, y_j) \\ = 0 & \text{for } (x,y) = (x_k, y_k), k \neq i, (x_k, y_k) \notin B \end{cases} \tag{6}$$

The weights of the local Shepard interpolation are defined below:

$$\begin{cases} w_j(x,y) = \dfrac{\frac{1}{\Psi_j^{\mu}}}{\sum_{i=1}^{N} \frac{1}{\Psi_i^{\mu}}}, 0 < \mu < \infty, \text{ with} \\ \Psi_j(x,y) = \begin{cases} \frac{R}{r_j} - 1 & \text{for } 0 < r_j < R, \\ 0 & \text{for } r_j \geq R \end{cases} \end{cases} \tag{7}$$

where r_j is the distance between the points (x,y) and (x_j, y_j):

$$r_j(x,y) = \sqrt{(x - x_j)^2 + *y - y_j)^2}, j = 1, \ldots, N \tag{8}$$

R represents the radius of circle, centered in the point (x,y), that determines those interpolation points (x_i, y_i) that are going to influence the interpolation function. We consider $\mu = 2$.

The N nodes can be seen as belonging to a rectangle defined by the coordinates (x_{min}, y_{min}) and (x_{max}, y_{max}), where:

$$\begin{aligned} x_{min} &= \min\{x_j | j = 1, \ldots, N\} \\ x_{max} &= \max\{x_j | j = 1, \ldots, N\} \\ y_{min} &= \min\{y_j | j = 1, \ldots, N\} \\ y_{max} &= \max\{y_j | j = 1, \ldots, N\} \end{aligned} \tag{9}$$

The rectangle area that contains all the interpolation points is:

$$A = (x_{max} - x_{min})(y_{max} - y_{min}). \tag{10}$$

The minimum value of R can be easily approximated. We associate to each node (x_j, y_j) a region that has the area equal to A/N. If the N initial nodes would be uniform distributed then each region should contain only one node (Figure 4).

R minimum is, in fact, the diagonal of the rectangle of area A/N.

The idea is to propagate the local properties, introduced by the initial N nodes, to all points. We start from the point:

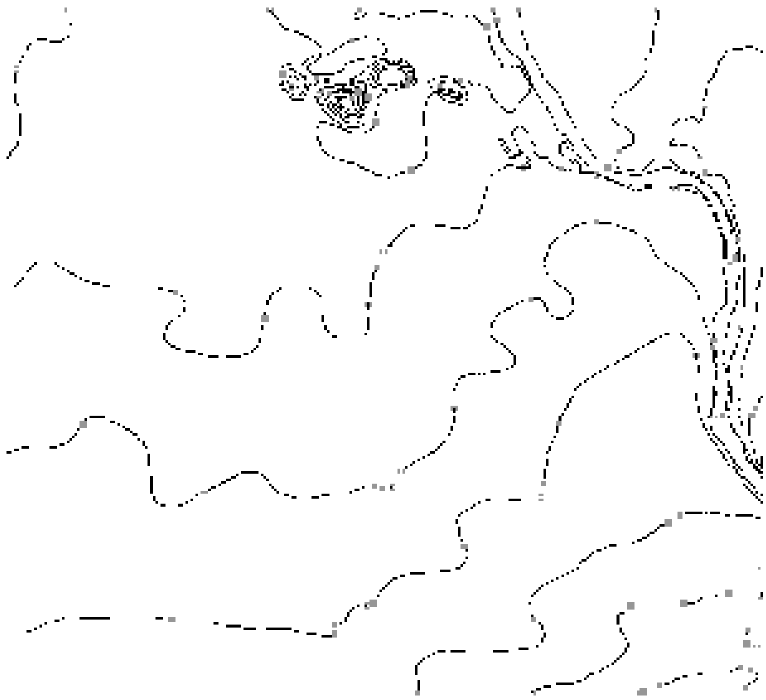

FIGURE 1. The data set representing Dealul Melcilor (Braşov) (isoline representation)

$$x_{CM} = \frac{\sum_{i=1}^{N} x_i \cdot f(x_i, y_i}{\sum_{i=1}^{N} x_i} \tag{11}$$

$$y_{CM} = \frac{\sum_{i=1}^{N} y_i \cdot f(x_i, y_i}{\sum_{i=1}^{N} y_i} \tag{12}$$

The starting point can be chosen, as well, by other techniques: clustering, visual inspection, etc.

Algorithm CONTROLLED LOCAL SHEPARD INTERPOLATION

InputData: A set of N nodes on a plane, the number of columns and rows used for re- sampling, the coordinates of the starting point (optional)

Outputata: A uniform data set

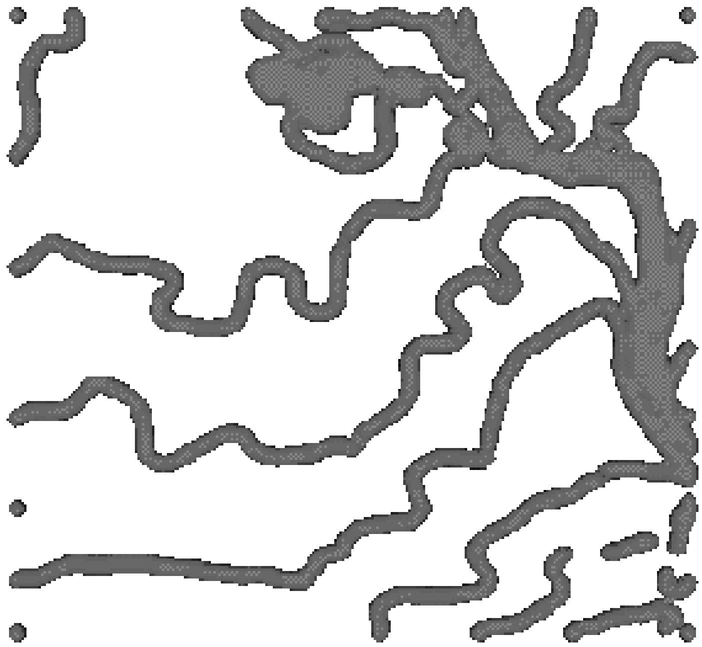

FIGURE 2. The data set representing Dealul Melcilor (Brasov) (visualized by the splatting technique and the iso- surfaces generation)

(1) For the N node we find x_{min}, y_{min}, x_{max} and y_{max}.
(2) We compute R minimum.
(3) We generate the uniform data set.
(4) We search for the starting point for interpolation.
(5) We use the above described interpolation function to compute the attribute value.
(6) We insert the computed value in the set of the interpolation points.
(7) We repeat the steps 5 and 6 covering the nodes in a spiral motion for the whole grid.

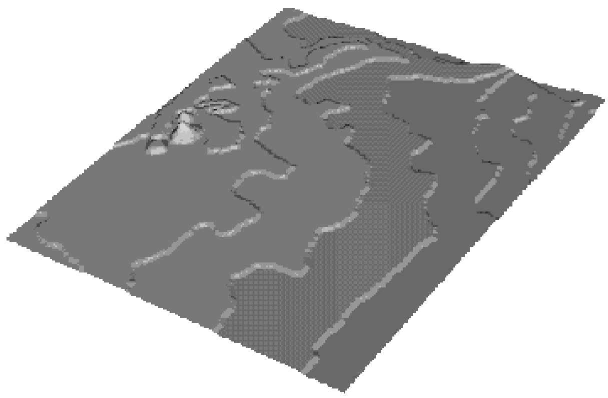

FIGURE 3. Visualization of the uniform distributed data set, representing Dealul Melcilor (Brasov) (warping technique); the warping factor is exaggerated for better perception

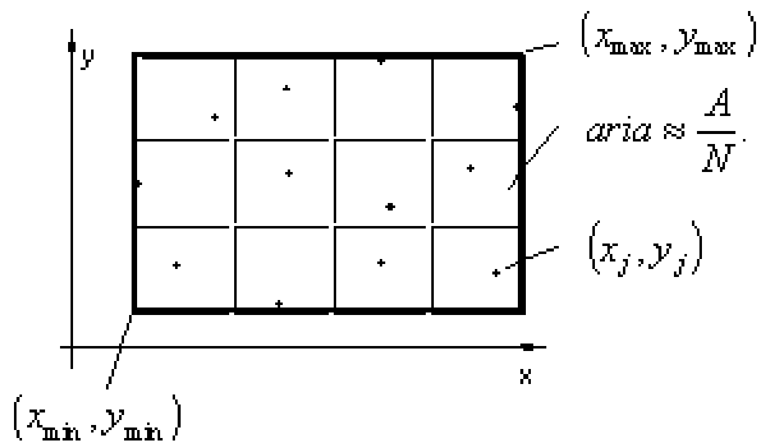

FIGURE 4. The rectangle with all the interpolation points

3. WARPING

The 3D reconstruction of the terrain is performed by warping taking into account the corresponding altitude of each point. The warping is done by the movement of the points of a 2D surface following the normal direction to the surface. The warping is controlled by a scaling factor (Figure 3).

4. Artificially associated colors

The perception of the terrain characteristics could be improved by colors artificially associated to each point, the color mapping taking into account the altitude.

Generally, if there is no attribute to be directly mapped into a color table, the necessary attributes have to be generated. A filter producing scalar values corresponding to a certain altitude does the scalar generation.

5. Conclusions

The 3D visualization of the terrain remains a hot issue. The controlled local Shepard interpolation algorithm has to be further tested against standard data sets.

Our tests included:

- known uniform functions were sampled and the values were visualized;
- data sets were then sub-sampled uniformly or non-uniformly;
- resulted data set was used as input data for the modeling module implementing our modified Shepard algorithm;
- the starting point was automatically chosen or it was chosen as result of a visual inspection of the non-uniform distributed data set (Figure 2);
- the two visual objects, obtained from the initial data set and the interpolated data set, respectively, were visually inspected.

The 3D visualization of the terrain can be performed automatically if the proper interface is implemented.

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