CO-016

CARTOGRAPHY OF MOUNTAIN ROCKY AREAS, A STATISTICAL MODELING AND DRAWING OF ELEMENT ARRANGEMENTS

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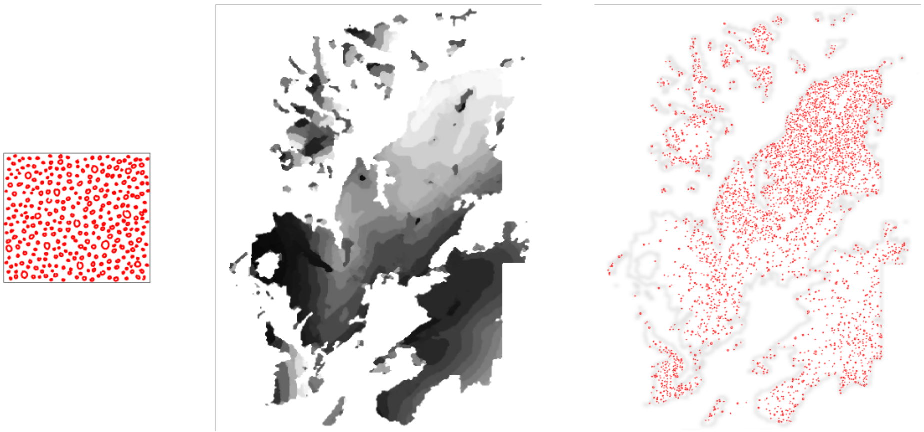
BACKGROUND AND OBJECTIVES

Over the past few years, the French National Mapping Agency (IGN France) implemented a policy of digitally producing base maps at 1:25 000 scale from its topographic vector database [6]. Mountain rocky areas are among the map elements that are the most difficult to produce with digital cartography. In the past, for the previous map's edition, they were drawn manually by experienced cartographers, using expressive graphic means. But this solution is very expensive and a new numerical solution must be found to replace this graphic means. A first numerical prototype [2] was produced and printed. Screes areas and rocky areas were badly perceived by experienced users during a user-study we conducted. Specific technical problems are also raised when producing a whole topographic map on a large surface of 1m x 1.20m with mountain areas using complex patterns for symbolisation.

Our previous approach was presented in the 6th ICA Mountain Cartography Workshop [2] and is based on two steps : the first step is the automated detection and classification of mountain areas (screes, rocks, glaciers...). The second step is the development of an adapted cartographic representation of rocks and screes areas. In this paper, we build on this previous approach proposing a more expressive and versatile method for the drawing of element arrangements areas such as screes areas. Based on a small patch of arranged elements, the proposed method is able to synthesize larger regions accordingly, and possibly varying locally some visual features such as the density of elements (see Figure 1).



a) Reference scree arrangement b) Density control map c) Synthesized arrangement

Fig. 1 – Given a reference scree arrangement (left), and a density control map computed from the digital elevation model (center), the proposed statistical model continuously renders a cartographic scree area (right) with respect to the expected density.

APPROACH AND METHODS

The proposed approach inherits a former artistic drawing method we proposed in the computer graphics community [3]. The synthesis step relies on a spatial marked point process [5]. Our goal through this paper is to demonstrate the interest of such statistical methods regarding mountain cartography issues.

The spatial marked point process we use is based on a Strauss Hard Core pairwise interaction model. This model captures second order statistics of the distances between elements. Let $||x_i-x_j||$ be the Euclidean distance between two random elements x_i and x_j. The interaction probability, that is the appearance probability, of these two elements at this relative distance is given by a three-steps piecewise function along $||x_i-x_j||$. A first step where the interaction value is zero indicates an interval $[0,h]$ of relative distances that cannot be observed between elements. In other words, h is an inhibition distance and two elements cannot be closer than h. A second interval $[h, r]$ delimits the relative distance space where the occurrence probability is . In order to be mathematically sound, in a third interval $[h,+\infty[$, the interaction model ends up almost surely (see Figure 2). This means that above a certain relative distance r, elements can be considered as arranged randomly. This model allows to draw arrangements of element that vary from regularly spaced to strongly random. Besides, this model can be refined by embedding possibly different element types according to their appearance (small/medium/big screes for instance).

$$c(x_i, x_j) = \begin{cases} 0 & \text{if } ||x_i - x_j|| < h \\ \gamma & \text{if } h \leq ||x_i - x_j|| < r \\ 1 & \text{otherwise} \end{cases}$$

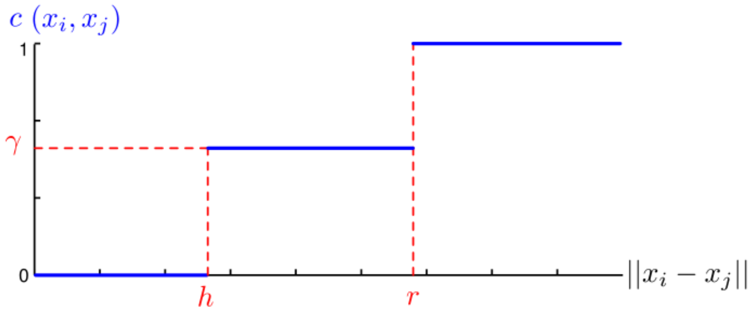


Fig. 2 – The Strauss Hard-Core interaction model represents the occurrence probability of a pair of elements along their relative Euclidean distance. In the scree results, we make use of two types of elements : small and big screes.

This interaction distance is embedded in a Gibbs probability density function (PDF). This PDF also integrates first-order probabilities for each element type. Each of these first-order probability represents the occurrence intensity of this type of elements. The whole model use 3N(N+1)/2 parameters where N is the number of element types. These parameters can be estimated on a small arrangement example using likelihood maximization for instance. It can also be interactively tuned by hand in our context since we are using just one different texture example (Figure 1a). Once all these parameters are fixed, a Monte Carlo sampling method is subsequently able to reproduce the same kind of arrangement at any given scale. The third section of our expressive rendering paper [3] gives all the technical details according to these two last steps.

The rendering of mountain cartography raise several new issues compared to purely artistic texture synthesis. Readability is a key aspect involved in cartography. Mountain cartography areas such as screes and rocky areas should somehow adapt to the local context (to maintain readability) yet still be coherent both in a same region and as a global feature that may repeat in several parts of a map. Therefore we propose to consider these areas as regions filled with textures based first on a unique example patch (coherence) but also that locally adapt and correlate to some local information (readability and expressivity). Instead of letting manually vary the textures as in [3], cartography offers an interesting context where we can let the textures vary according to many available measures (altitude, contextual map information, etc.).

A first visual feature that let locally vary the texture which was also used in [3] is the local density of element occurrence. This local density can be easily controlled through the sampling model since it corresponds to the first-order statistics. This scalar field associates a density value to each point of the map. The different ways to compute this scalar field open many interesting results. Straightly using the elevation map for instance for the rocky areas will lead to more dense regions when the altitude raises. A more realistic solution might be to vary rocks according to the local gradient of altitude and thus get closer to the representation of cliffs when the altitude drops abruptly. In the results section, we will present different ways to compute density dealing with screes.

Several additional visual features can be investigated to again locally vary the textures : element's color (or greyscale value), orientation and size. Some other features are more specific to anisotropic or line-based element (such as escarpment elements) : element's length, curvature, intersections. All these features cannot be easily manipulated by a user. However, in the cartography context, we can control all these features by again relating them to local combination of measures via the computation of some bi-variable fields. Let notice that unlike density, some of these features require multidimensional fields (color, orientation).

RESULTS

For this first collaboration, we focused on scree areas. This solution will be extended to other type of elements in the future. Figure 3 shows on the same area our previous approach and the one proposed in this paper. Left, a repetitive scree texture is regularly patched on binary regions. Scree areas are filled with this texture while holes are left empty. This solution though being computationally simple gives a strong computerized visual impression mainly due to its strong repetitivity. Besides, in more complex context where more information should be included, we may not want a constant 100% scree filling. Right of Figure 3 shows a more varying texture where positive scree areas are filled with an arrangement of scree elements. The scree elements are picked out from a scree example patch (Figure 1a). They are individually resampled on demand and according to the statistical model that has been learnt on the example patch.

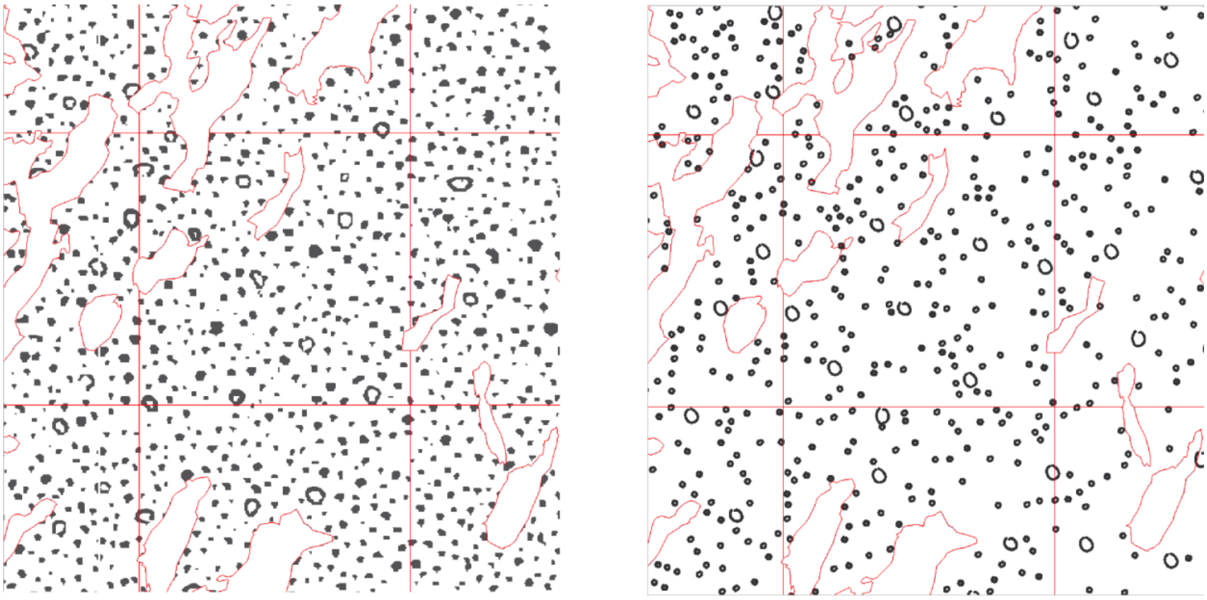
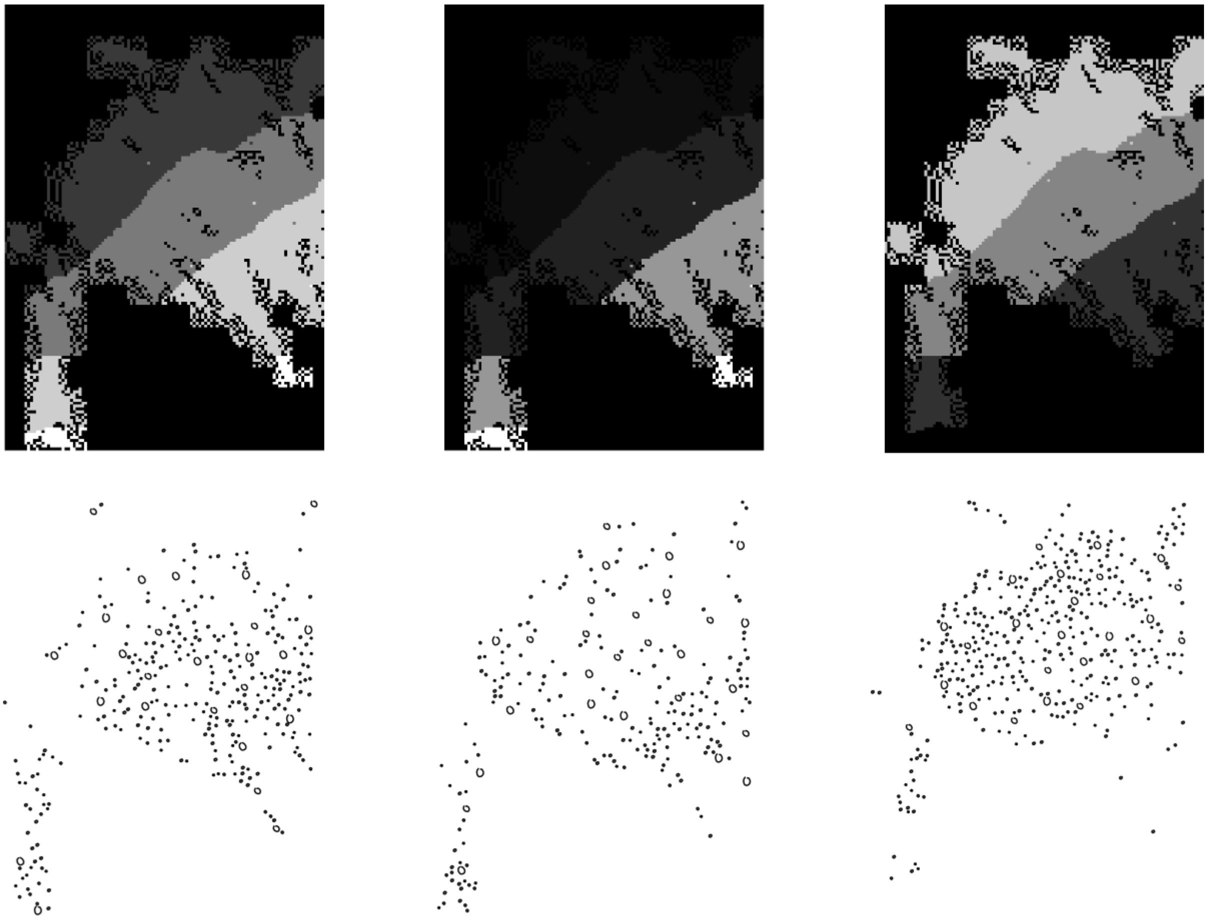


Fig. 3 – Symbolisation of screes areas (limits in red) with a pattern (on left) and with 6 vectorial symbol element extracted from the pattern (on right).

Figure 4 shows various density profiles that can be applied during the sample of scree elements. Since screes often accumulate down severe sloppy areas, it might be a relevant solution to control their density according to local slope inside an area. In this Figure, we propose to consider individually every connected components of scree areas. Based on the MNT, we build an histogram equalization of the intensity values. Therefore, for each connected component of scree regions, 100% values will be fixed in the highest altitudes and 0% in the lowest altitude of this region. A mapping function can then be applied between this locally equalized version of the MNT and the scree density. Figure 4 show three different mapping functions.



a) b) c)

Fig. 4 – Three examples of density profiles (first row). These profiles are based on the MNT. On bottom row, a) density follows the MNT with a $x \propto (1\text{-}x)$ *law. This leads to higher density down the scree areas (simulating the accumulation of screes). It is combined with a 20% cutoff to prevent from blank or very poor areas. b) density follows the MNT with a* $x \propto (1\text{-}x)^2$ *law combined with a 20% cutoff. This increase the variation speed towards higer densities. c) density follows the MNT with a* $x \rightarrow \propto x$ *law. This leads to higher scree density up the scree areas.*

Since each scree element can be manipulated, more controls are available to improve the expressiveness of the rendered scree areas. Figure 5 show three examples where orientation and grayscale intensity are investigated.

a) b) c) d)

Fig. 5 – Since each scree can be individually and continuously manipulated, many controls can be used to improve expressiveness. a) same as Fig 4a. b) a random orientation is given to each scree element. c) random orientation and random gray intensity is given to each element. d) random orientation and a gray intensity that is correlated with the MNT. Higher screes are darker.

On Figure 6, a more realistic example where more layers of cartographic information are included. This example is taken from a bigger experiment on a real IGN map format above mountainous regions. Above 50'000 scree elements are sampled on the whole map. The computational time for thissampling is 20 minutes on a dual-core laptop, using a C-based implementation [7].

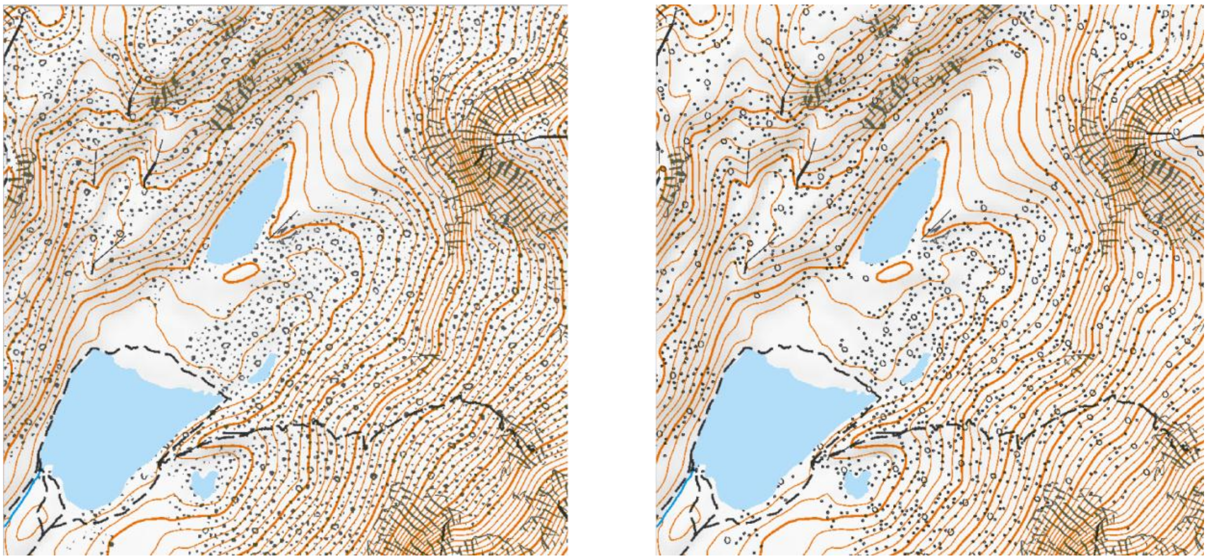


Fig. 6 – Comparative result including level-lines and other pieces of information above a scree area. Left, a repetitive scree texture delivers a dense impression. Right, the varying density of scree elements offers a more expressive visual appearance. The entire IGN printed map for this regions contains over 50'000 scree elements. These results have been generated with Mercator® software.

CONCLUSION AND FUTURE PLANS

We proposed in this paper a statistical drawing approach to the problem of mountain cartography. This method maintains first a good coherence among the different similar areas by using a texture synthesis approach. Due to its vectorial element-based nature, it also allows the implementation of a variety of controls to vary the local rendering of these textures, hence improving its expressivity. This second aspect goes towards an automation of the previous manually drawing of mountain rocky areas. The proposed method goes beyond the limitations of two previous schemes from the computer graphics domain [1, 4], which neither allow density control and irregular arrangements nor investigate the control of other visual features.

As presented in the background section, our approach is first based on the automated detection and classification of mountain areas (screes, rocks, glaciers...) from the calibrated orthophotos . An interesting future work would be to take advantage of these orthophotos by extracting some geometrical cues like ridges and significant escarpments. Redraw some of these geometrical cues and mix them with the previous textured arrangements would improve the realistic information contained in the mountain areas without hopefully losing its readability power. A perhaps simpler approach toward that goal might also be to use these orthophotos to guide and control directly the positions and visual features of the drawn elements. The real in situ density of screes in the orthophotos for instance could guide the drawn density. Managing the possible occlusions created by projected shadows would be an important issue since these type of occlusions are frequent in mountain areas.

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