ReScience

[Re] Weighted Voronoi Stippling

Nicolas P. Rougier[1,2,3]

1 INRIA Bordeaux Sud-Ouest, Bordeaux, France. **2** LaBRI, Université de Bordeaux, Institut Polytechnique de Bordeaux, Centre National de la Recherche Scientifique, UMR 5800, Talence, France. **3** Institut des Maladies Neurodégénératives, Université de Bordeaux, Centre National de la Recherche Scientifique, UMR 5293, Bordeaux, France.

Nicolas.Rougier@inria.fr

Editor
Name Surname

Reviewers
Name Surname
Name Surname

Received Feb, 1, 2017
Accepted Feb, 1, 2017
Published Feb, 1, 2017

Competing Interests:
The authors have declared that no competing interests exist.

Article repository

Code repository

Data repository

A reference implementation of

→ Weighted Voronoi Stippling, Adrian Secord. In: Proceedings of the 2Nd International Symposium on Non-photorealistic Animation and Rendering. NPAR '02. ACM, 2002, pp. 37– 43.

Introduction

Adrian Secord introduces in [6] a *techniques for generating stipple drawings from grayscale images using weighted centroidal Voronoi diagrams* as in *the traditional artistic technique of stippling that places small dots of ink onto paper such that their density give the impression of tone*. The paper is not accompanied by any code and, even though the webpage of the author points to a code archive, this one is actually nowhere to be found. We decided to replicate the method because it can be used for different purpose, especially in computational biology or neuroscience where the distribution of a cell population can be conveniently described by shades of grey. It is to be noted that since the publication of this paper, a number of related techniques have been proposed [1][2][3][4] that may be more efficient but with lower quality. We thus privileged this implementation that is simple and provides high stippling quality.

Methods

We applied the method proposed in the original paper with some variations due to the non-use of the GPU for computing the Voronoi diagram. In the original article, author computes the Voronoi diagram by taking advantage of the graphic card (GPU) and the fact that a set of cones seen from above actually represents a Voronoi diagram (see [5]). We use instead the QHull library (through the Scipy Python package) for computing the Voronoi diagram together with the Voronoi regions (as a list of segments). We also took care of adding extra points such that each cell is contained within a user-defined bounding box that will be set to the dimension of the density image. For computing the weighted centroid, we applied the definition proposed in the original paper over the discrete representation of the domain:

$$\mathbf{C}_i = \frac{\int_A \mathbf{x}\rho(\mathbf{x})dA}{\int_A \rho(\mathbf{x})}$$

However, we did not use the proposed optimization. Instead, each cell is rasterized (as a set of pixels) and the centroid is computed using the integrals over the whole set of pixels composing the Voronoi cell. As noted by the author, the precision of the method is directly related to the size of the Voronoi cell. Consequently, if the original density image is too small relatively to the number of stipples, there might be quality issues. Finally, we used a fixed number of iteration ($n = 50$) instead of using the difference in the standard deviation of the area of the Voronoi regions as in the original paper since the definition of the rejection criterion was not clear in the original article and quite arbitrary.

Results

We contacted the original author asking for permission to re-use the original images but did not obtain any response. We thus display here only the output of our replication to be compared with the original ones. The climbing shoe (figure 1) and the corn plant (figure 2) are very similar to the images displayed in the original article. However, for the large and small Peperomia plants (figure 3 & 4), the output of our replication is clearly at a lower quality without having identified the cause. Most probably, the limited resolution of the input image may be a critical factor and it is not clear if the author used these small resolution versions or if he used higher resolutions.

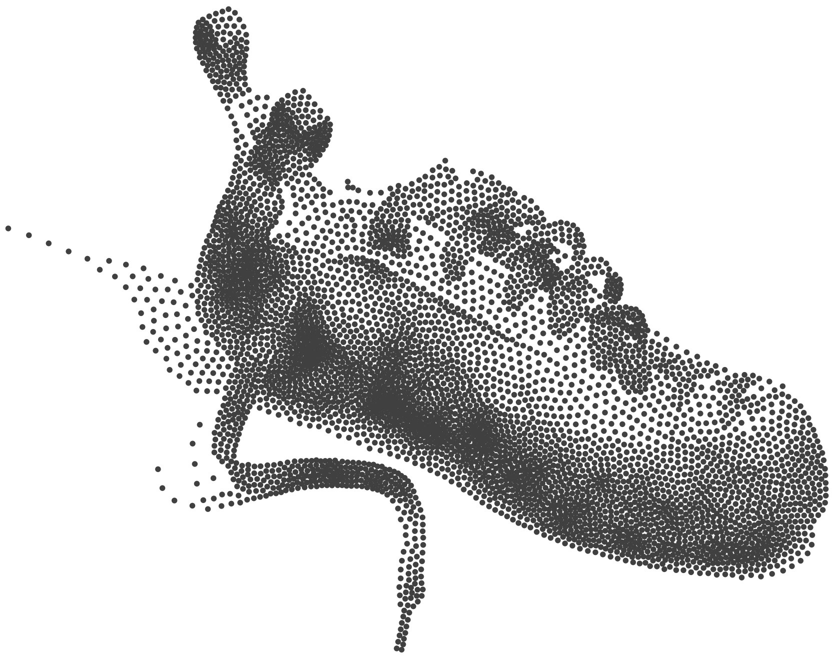

Figure 1: Climbing shoe (1300x1300), 5 000 dots, 50 iterations, point size 3

We also provide a new set of data that is freely usable for future comparison (CC0 licence).

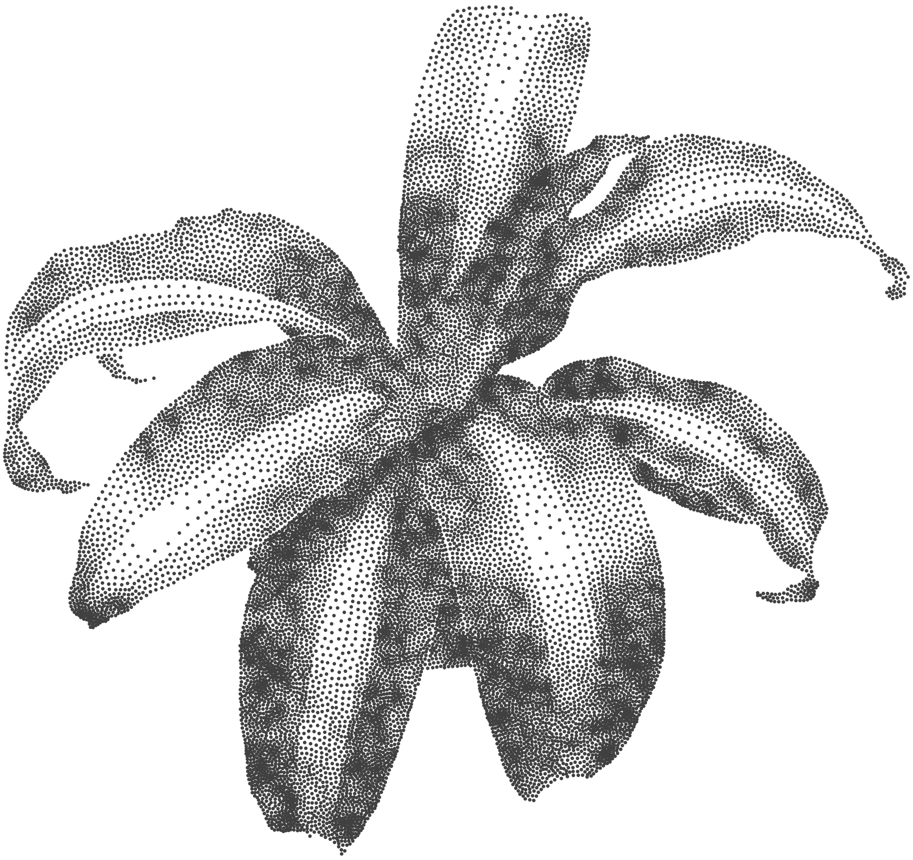

Figure 2: Corn plant (991x934), 20 000 dots, 50 iterations, point size 1.5

Figure 3: Large Peperomia plant (700x700), 20 000 dots, 50 iterations, point size 2.0

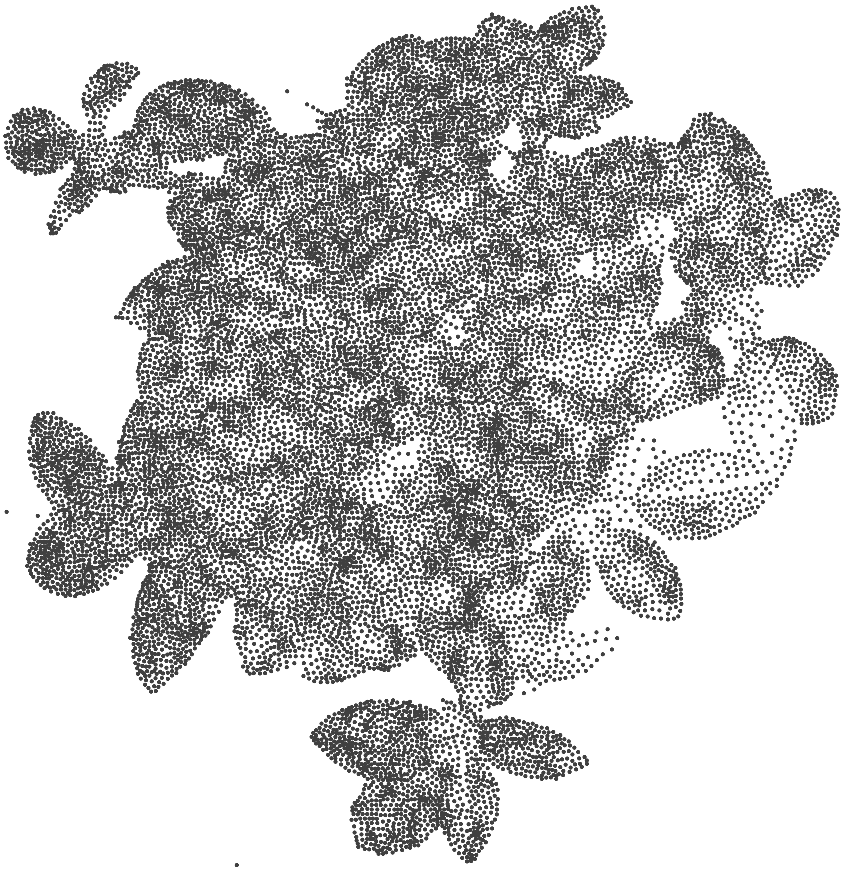

Figure 4: Small Peperomia plant (400x400), 20 000 dots, 50 iterations, point size 1.0

Figure 5: Boots (1280x853), 20 000 dots, 50 iterations, variable point size [0.5,2.5]

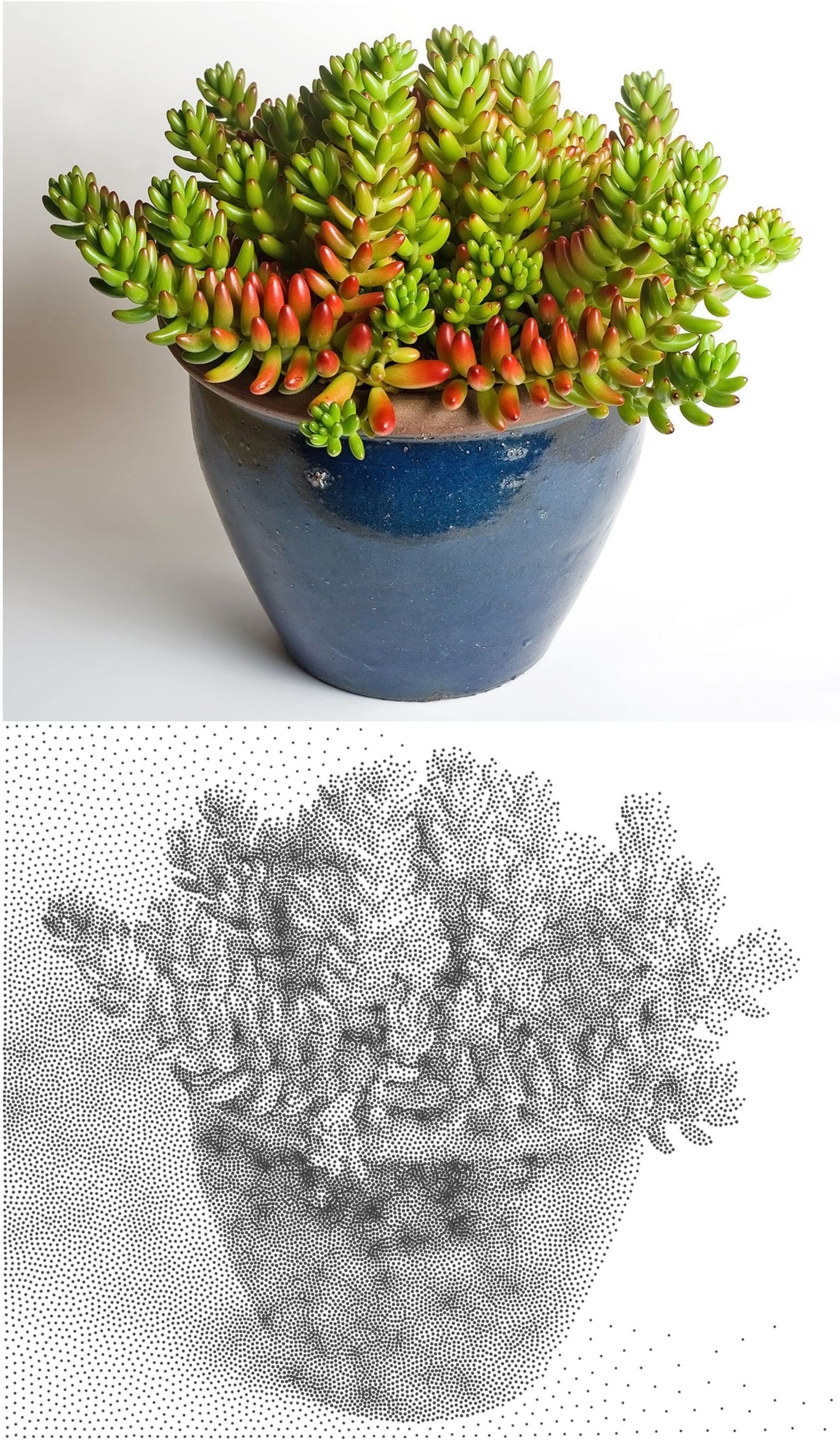

Figure 6: Pot plant (1195x1024), 20 000 dots, 50 iterations, variable point size [0.5,2.0]

Figure 7: Leafs (1195x1024), 20 000 dots, 50 iterations, variable point size [0.5,2.0]

Conclusion

Most of the results have been replicated even though some discrepancies remain in the final output. Without further contact with the original author, it is difficult to identify the precise cause but most likely, the problem occurs because of the very limited resolution of the input picture.

References

[1] I Ascencio-Lopez, O Meruvia-Pastor, and Hugo Hidalho-Silva. "Adaptive incremental stippling using the Poisson-disk distribution". In: *Journal of Graphics* 15.1 (2010), pp. 29–47.

[2] Michael Balzer. "Capacity-Constrained Voronoi Diagrams in Continuous Spaces". In: *2009 Sixth International Symposium on Voronoi Diagrams*. IEEE, 2009, pp. 79–88.

[3] Michael Balzer, Thomas Schlömer, and Oliver Deussen. *Capacity-constrained point distributions: a variant of Lloyd's method*. Vol. 28. a variant of Lloyd's method. ACM, July 2009.

[4] R Bridson. "Fast Poisson disk sampling in arbitrary dimensions." In: *SIGGRAPH sketches* (2007).

[5] Kenneth E. Hoff III et al. "Fast Computation of Generalized Voronoi Diagrams Using Graphics Hardware". In: *Proceedings of the 26th Annual Conference on Computer Graphics and Interactive Techniques*. SIGGRAPH '99. ACM Press/Addison-Wesley Publishing Co., 1999, pp. 277–286.

[6] Adrian Secord. "Weighted Voronoi Stippling". In: *Proceedings of the 2Nd International Symposium on Non-photorealistic Animation and Rendering*. NPAR '02. ACM, 2002, pp. 37–43.