Mapping NDFs to Heightfields

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1 What is an NDF?

An NDF, or Normal Distribution Function, denotes the distribution of angles among normal vectors of a surface. It indicates how steep or flat a surface is, and the direction its slope is in
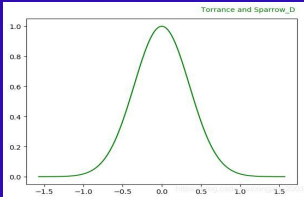

Figure 1: An example of an NDF. Angles of normal vectors are on the x-axis, relative frequencies are on the y-axis. The green line shows the distributed frequencies of normal angles. [1]

2 What is a Heightfield?

A Heightfield, or Heightmap, is a 2D representation of a surface. The coloration of the Heightfield indicates how high or low points are on it relative to each other. Heightfields can also be mapped to a 3D representation
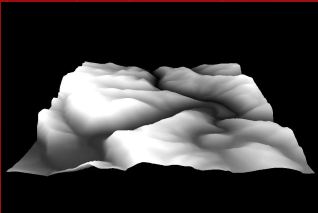

Figure 2: An example of a Heightfield. Darker colors indicate lower height, lighter colors indicate higher height. [2]

3 Research question

Given an NDF, how can generate a corresponding Heightfield using simple optimization algorithms?

4 Research method

An algorithm is created using the Simulated Annealing optimization method.

The algorithm is provided with an NDF to map to a Heightfield, and begins its mapping with a flat Heightfield. The algorithm goes through a pre-defined number of iterations, each iteration changing one random point on the Heightfield and measuring if the NDF of this new Heightfield is closer to the target than before, using the mean squared error between the two graphs, and chooses either the previous or new Heightfield for the next step based on this score.

A "temperature" variable is used throughout the algorithm's iterations, which slowly decreases. This variable governs a chance of the algorithm accepting a "lesser" solution in pursuit of the global optimum. A lower temperature means a lower probability.

The algorithm terminates either if the target and measured NDF are identical for one step (a.k.a. their mean squared error is 0), or the pre-defined number of iterations is reached.
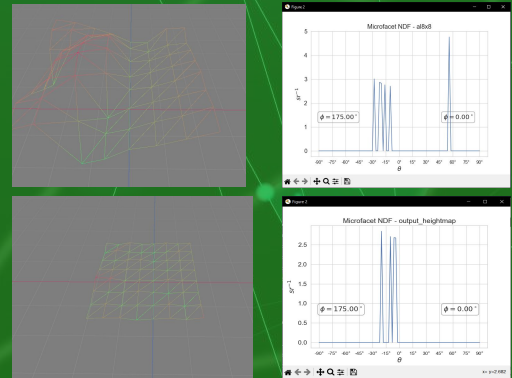
5 Results

Figure 3: Top-left is a Heightfield whose NDF is measured (shown top-right). This NDF is the target NDF in the algorithm. Bottom-right is the Heightfield created by the algorithm, with its NDF shown bottom-right. In both Heightfields, red hues mean higher altitude, and green hues mean lower altitude

6 Conclusion

The algorithm appears to work, however it is still quite slow and needs a lot of iterations to complete its task due to the randomness of Simulated Annealing. If given enough time for calculation and exploration of different possible Heightfields, the algorithm will successfully complete the mapping.

References

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3. Aarts, E. E., & Laarhoven, V. P. P. (1989). *Simulated annealing: An introduction.* Statistica Neerlandica, 43(1), 31–52. https://doi.org/10.1111/j.1467-9574.1989.tb01245.x