Supplemental Material Deep Generative Framework for Interactive 3D Terrain Authoring and Manipulation

Anonymous WACV submission

Paper ID 1311

1. Related Work

In this section, we provide an overview of existing example based terrain authoring and modelling techniques.

Terrain Authoring and Modelling

Largely, synthetic terrain generation has been accomplished through a wide array of techniques from manual editing which is often laborious, to automatic generation without any user intervention. These can be broadly categorised as procedural, simulation based and example-based techniques. [5] provides an overview as well as critical comparison of existing terrain authoring and modelling techniques.

Procedural generation try to reproduce the effects of physical phenomenons without simulating them. They do not use real-world data, instead use the observation derived from the real world examples and try to replicate the same, using algorithms. They either synthesize the terrain over entire plane or a large domain using self similar properties or synthesize specific land forms such as mountain ranges, rivers or canyons. They often use some fractal noise that produce patterns similar to real world terrains. Fractional Brownian motion [8] is most commonly used for such modelling. [2, 1] generate terrains using fractal methods around predefined constrains by user in the form of rivers or ridge lines. Subdivision schemes refine the initial terrain in iterative manner to introduce finer details. Although they can be used to model very large terrains, they fail to capture high level patterns found in real world terrains. [4] is one of the earliest sketch based interfaces that allowed interactive modeling of terrains. [6] hierarchically combines primitives to represent variety of land forms. To overcome the unrealistic recursive patterns generated by fractal methods, subdivision process use the user provided constraints to render terrains.

Simulation based methods generate terrains by performing simulation of real world phenomenon like thermal, hydraulic erosion, weathering *etc*. Thermal erosion is caused due to thermal weathering and mass movement of rocks and sedation [10]. [11] synthesises cliffs and hangovers by 3D volumetric thermal erosion. Tectonic simulations are applied to large scale terrains, and also take into account the effects caused by deformation of underlying tectonic plates [9]. Hydraulic erosion is caused by flow of motion against bedrock. These may be applied to terrains produced from fractal procedures to make them realistic. [7] perform fluid simulation using Smoothed Particle Hydrodynamics (SPH) method, and a physically-based erosion model adopted from an Eulerian approach. [3] combine the effects of hydraulic simulation and vegetation for terrain synthesis. Simulation methods are computationally expensive and lacks user control.

2. Dataset Preparation

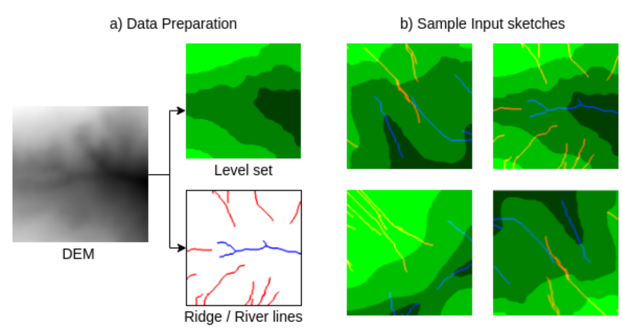

Figure 1. a) We extract the topographic map sketches from the ground truth DEMs. b) Some examples of the input sketches after extraction and combining the level set and ridge /river lines.

We prepare the training dataset by extracting the topographic map input sketches from DEMs, as depicted in Figure 1. We extract the high altitude mountain ranges as ridge lines and the low altitude regions as valley lines. The red channel of the image is used to represent the ridge lines and the blue channel is used for valley lines. We threshold the entire DEM at four levels to prepare the level set. Any number of levels can be used to prepare the level sets. More levels would help provide more user control, however, it might be difficult for user to hand draw. The green channel is used

Kernel Size	MSE
None	28.4025
3x3	28.3436
5x5	28.3335
7x7	**28.3231**
11x11	28.3267
21x21	28.4873

Table 1. MSE loss with different Gaussian filters.

to represent the level sets. Some sample input sketches are also shown in Figure 1.

3. Failure Cases

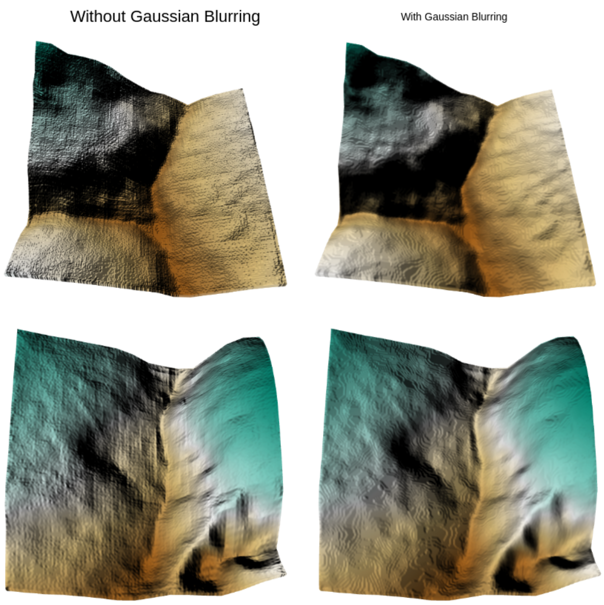

Figure 2. Gaussian blurring is applied to remove grid patterns.

There are grid like patterns that appear on the generated terrains, due to upsampling in the generator network, as shown in Figure 2. We apply a simple Gaussian blurring to remove them, and make it visually more appealing. We calculate the MSE loss for different kernel sizes as shown in Table 3. We observe that use of Gaussian blurring gives a little improvement in the MSE values and the visual improvement is apparent.

References

[1] Farès Belhadj. Terrain modeling: A constrained fractal model. volume 07, pages 197–204, 01 2007. 1

[2] Farès Belhadj and Pierre Audibert. Modeling landscapes with ridges and rivers. In *Proceedings of the ACM Symposium on Virtual Reality Software and Technology*, VRST '05, page 151–154, New York, NY, USA, 2005. Association for Computing Machinery. 1

[3] Guillaume Cordonnier, Eric Galin, James Gain, Bedrich Benes, Eric Guérin, Adrien Peytavie, and Marie-Paule Cani. Authoring Landscapes by Combining Ecosystem and Terrain Erosion Simulation. *ACM Transactions on Graphics*, 36(4):134, July 2017. The paper was presented at Siggraph 2017. 1

[4] James Gain, Patrick Marais, and Wolfgang Stra. Terrain sketching. In *Proceedings of the 2009 Symposium on Interactive 3D Graphics and Games*, I3D '09, page 31–38, New York, NY, USA, 2009. Association for Computing Machinery. 1

[5] Eric Galin, Eric Guérin, Adrien Peytavie, Guillaume Cordonnier, Marie-Paule Cani, Bedrich Benes, and James Gain. A review of digital terrain modeling. *Computer Graphics Forum*, 38(2):553–577, 2019. 1

[6] Jean-David Génevaux, Eric Galin, Adrien Peytavie, Eric Guérin, Cyril Briquet, François Grosbellet, and Bedrich Benes. Terrain modelling from feature primitives. *Computer Graphics Forum*, 34(6):198–210, 2015. 1

[7] Peter Kristof, Bedrich Benes, Jaroslav Krivanek, and Ondrej Stava. Hydraulic erosion using smoothed particle hydrodynamics. *Computer Graphics Forum*, 28:219 – 228, 04 2009. 1

[8] Benoit B. Mandelbrot and John W. Van Ness. Fractional brownian motions, fractional noises and applications. *SIAM Review*, 10(4):422–437, 1968. 1

[9] E. Michel, Arnaud Emilien, and Marie-Paule Cani. Generation of folded terrains from simple vector maps. In *Eurographics*, 2015. 1

[10] F. K. Musgrave, C. E. Kolb, and R. S. Mace. The synthesis and rendering of eroded fractal terrains. In *Proceedings of the 16th Annual Conference on Computer Graphics and Interactive Techniques*, SIGGRAPH '89, page 41–50, New York, NY, USA, 1989. Association for Computing Machinery. 1

[11] A. Peytavie, E. Galin, J. Grosjean, and S. Merillou. Arches: a framework for modeling complex terrains. *Computer Graphics Forum*, 28(2):457–467, 2009. 1