# Instant generation of geomorphologically accurate terrain

(Masters-level internship, could be extended to a Ph.D.)

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*Figure 1: Simulations based on a geomorphology law can produce consistent mountains on massive scales (left), but they still need thousands of time steps. The goal of the project is to investigate novel ways to produce similar terrains with just a few iterations. The generation algorithm can be extended to incorporate the impact of sediment transport and deposition to shape, for example, the landforms in the right image (Google Earth, Death Valley, US).*

## Context and goal

Marketing, construction and risk assessment have recently joined the list of industries that are gradually converting to the digital era. This tendency necessitates the development of new modeling techniques that ease the authoring of massive yet convincing digital worlds.

In this project, we focus on terrains, a key element of the surrounding environment that is crucial to many virtual worlds. Our longer-term objective is to develop an editing tool, where the user would uses brushes to transmit a style, learned from a real landscape, to a synthetic one. We believe that such a tool would impact several industries, from visual effects to risk assessments, where the nature of the ground, and therefore its resistance to extreme stresses could be inferred from elevation data only.

The main goal of this internship is to build the cornerstone of this pipeline: a fast terrain generation tool, rooted on geomorphology laws.

## Approach

We will start from the Stream Power Law [4]: a simple yet expressive model for terrain generation. The key idea behind this model [1, 2] is to simulate a terrain as a series of time steps; during each of them we order the nodes of the terrain to compute the *discharge* (amount of water that flows through each point), a key quantity that, together with the slope drives the erosion.

The simulation of the Stream Power Law requires iterating other all the past time-steps. This is interesting for geologists, which strives to understand the past, but less so for computer graphics, where focus on present-day topographies. A first task will be therefore to explore analytical solutions of the SPL, that where known for 1D cases but only very recently extended to 2D maps [3]. The bottleneck of that approach is the drainage network, that needs to be iteratively improved to cope with the analytical solution, with number of iterations of the order of the width of the terrain, which seriously limit the benefits of an analytical solution. Therefore, we will explore multi-scale approaches to solve this limitation.

A second issue is that previous implementations of the SPL do not include sediment transport and disposition: the eroded material is completely washed out of the simulation domain. A second task will therefore be to implement an improvement of the SPL to account for sediment deposition [5]. The main challenge will be to couple this sediment model with the analytical solution developed in the first part. We believe that solving these problems will bring significant contributions to computer graphics with faster and more diverse terrain generation, but also in geosciences where analytical solutions are only emerging.

## Work environment and requirements

The internship will take place at Inria Sophia Antipolis in the GRAPHDECO group (http://team.inria.fr/graphdeco). Inria will provide a monthly stipend of around 1100 euros for EU citizens in their final year of masters, and ~600 euros for other candidates.

Candidates should have strong programming and mathematical skills with knowledge in computer graphics and experience in Python data science libraries. Interest in geology/mountaineering/outdoors activities is a plus. The project might extend to a Ph.D. position on a topic that relates terrain generation to machine learning, and for which experience in optimization and machine learning is required.

## References


[1] Jean Braun and Sean Willett. 2013. A very efficient O (n), implicit and parallel method to solve the stream power equation governing fluvial incision and landscape evolution. *Geomorphology* 180, (2013), 170–179.

[2] Guillaume Cordonnier, Jean Braun, Marie-Paule Cani, Bedrich Benes, Eric Galin, Adrien Peytavie, and Eric Guérin. 2016. Large scale terrain generation from tectonic uplift and fluvial erosion. *Computer Graphics Forum* 35, 2 (2016), 165–175.

[3] Philippe Steer. 2021. Short communication: Analytical models for 2D landscape evolution. *Earth Surface Dynamics* 9, 5 (September 2021), 1239–1250. DOI:https://doi.org/10.5194/ESURF-9-1239-2021

[4] Kelin X Whipple and Gregory E Tucker. 1999. Dynamics of the stream-power river incision model: Implications for height limits of mountain ranges, landscape response timescales, and research needs. *Journal of Geophysical Research: Solid Earth (1978–2012)* 104, B8 (1999), 17661–17674.

[5] X P Yuan, J Braun, L Guerit, D Rouby, and G Cordonnier. 2019. A New Efficient Method to Solve the Stream Power Law Model Taking Into Account Sediment Deposition. *J Geophys Res Earth Surf* 124, 6 (2019), 1346–1365.