Inverse Procedural Generation of Geological Stories

Master Internship Proposal

Supervised by Marie-Christine CACAS-STENTZ, IFPEN
Marie-Paule CANI and Rémi RONFARD, IMAGINE team, INRIA Grenoble Alpes
E-mail : remi.ronfard@inria.fr

Context

Hand-drawn sketches are useful in geology for illustrating and validating hypotheses, but they are limited. In addition to representing only one 2D slice of the terrain being investigated, they can only represent hypotheses on the underground composition at discrete time steps, rather than a complete history. Insuring consistency between these sketches over time heavily depends on the skills of the geologist, and on his knowledge on the way geologic slices of soil fold, on the way cracks propagates and produce sliding, and on the way sediments are deposited. Exploring different hypotheses is very difficult, if not impossible, with the current pipeline.

Recently, it was proposed to organize geological sketches into « story trees » to present and compare different interpretations of the formation of a given terrain [1] but the task remains labor-intensive, requiring the geologist to draw every sketch in the story tree. In this internship, we would like to follow up on this line of research by proposing methods for inferring a geological story tree directly from a single geological sketch, and presenting the resulting tree of possible geological stories as an animation.

Objectives

While previous work has investigated methods for generating 3D models from annotated 2D geological sketches or seismic slices [2], little work has been devoted to the complementary problem of interpolating geological sketches over time. More importantly, no automatic method for inferring and visualizing possible pasts from a single sketch representing the present situation was proposed. This is the goal of this internship: the general methodology will be to compute inverse physically-based simulations, going backwards in time, from an input geological sketch

representing an instant in time. Due to discrete events such as cracks, this process will result into not only one, but a number of plausible explanations of the past. The result will be stored as a tree of possible geological stories, to be visualized and further refined by the geologist.

Starting from a single hand-drawn sketch of a longitudinal slice of the earth, the backward simulation will consist of both continuous and discrete components. Continuous deformations (preserving the topology) such as the inverse effect of erosion, or sediment deposition, slice compression and of fold creation/suppression will be implemented by changing the width of the corresponding slices, or pushing and pulling the land in physically-plausible directions to change curvature. Discrete deformations (resulting in topology changes) such as fault networks creation/suppression will be implemented as stochastic binary trees as proposed by Nicolas Cherpeau and co-workers [3], resulting in branches in the story tree.

One important aspect of geological structures is their topological complexity, resulting in highly non-manifold substructures of volumes, surfaces, folds, cracks and faults. To deal with this complexity, the input sketch will be represented as a vector graphics complex [4], a data structure which has been shown to model all possible incidence relations between vertices, edges and faces in 2D sketches. The output animation will be represented as a vector animation complex [5], which can describe all possible changes in the topology of a vector graphic complex over time.

Using the open-source « vpaint » software [6], the intern will design and implement tools for quickly creating geological animations from a single geological sketch. The work will focus on proposing methods for computing the story tree based on an analysis of the sketch topology; backward-simulating each branch in the story tree; and displaying the story tree as a branching tree of vector graphics animations. Crucially, methods proposed for controlling the number of branches in the story graph [7] will need to be adapted for the special case of geological stories.

References

[1] Lidal, Endre Mølster; Natali, Mattia; Patel, Daniel; Hauser, Helwig; Viola, Ivan. Geological storytelling. *Computers & graphics.* 37: 445-459.

[2] Amorim, Brazil, Samavati, Sousa. 3D geological modeling using sketches and annotations from geologic maps. *Sketch-Based Interfaces and Modeling* (SBIM '14).

[3] Nicolas Cherpeau, Guillaume Caumon, Bruno Lévy. Stochastic simulations of fault networks in 3D structural modeling. Comptes Rendus Géosciences, Acad´emie des Sciences / Elsevier Masson, 2010, 342 (9), pp.687-694.

[4] Boris Dalstein, Remi Ronfard, Michiel Van De Panne. Vector Graphics Complexes. ACM transactions on Graphics, Proceedings of ACM SIGGRAPH 2014.

[5] Boris Dalstein, Rémi Ronfard, Michiel van de Panne. Vector Graphics Animation with Time-Varying Topology. ACM Transactions on Graphics, 34, 4, Proceedings of ACM SIGGRAPH 2015.

[6] http://www.vpaint.org/

[7] Mark Riedl and Michael Young. From Linear Story Generation to Branching Story Graphs. IEEE Computer Graphics and Applications Special Issue on Interactive Narrative, 2006.