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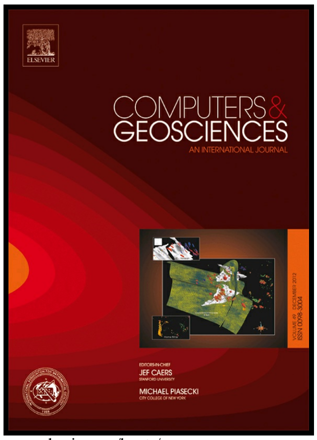

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PII: S0098-3004(17)30113-9
DOI: http://dx.doi.org/10.1016/j.cageo.2017.05.012
Reference: CAGEO3966

To appear in: *Computers and Geosciences*

Received date: 2 February 2017
Revised date: 22 May 2017
Accepted date: 25 May 2017

Cite this article as: Júlio Hoffimann, Céline Scheidt, Adrian Barfod and Je Caers, Stochastic Simulation by Image Quilting of Process-based Geologica Models, *Computers and Geosciences* http://dx.doi.org/10.1016/j.cageo.2017.05.012

Stochastic Simulation by Image Quilting of Process-based Geological Models[☆]

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Abstract

Process-based modeling offers a way to represent realistic geological heterogeneity in subsurface models. The main limitation lies in conditioning such models to data. Multiple-point geostatistics can use these process-based models as training images and address the data conditioning problem. In this work, we further develop image quilting as a method for 3D stochastic simulation capable of mimicking the realism of process-based geological models with minimal modeling effort (i. e. parameter tuning) and at the same time condition them to a variety of data. In particular, we develop a new probabilistic data aggregation method for image quilting that bypasses traditional ad-hoc weighting of auxiliary variables. In addition, we propose a novel criterion for template design in image quilting that generalizes the entropy plot for continuous training images. The criterion is based on the new concept of voxel reuse—a stochastic and quilting-aware function of the training image. We compare our proposed method with other established simulation methods on a set of process-based training images of varying complexity, including a real-case example of stochastic simulation of the buried-valley groundwater system in Denmark.

Keywords: Voxel reuse, Shannon entropy, Relaxation, Tau model, Multiple-point statistics, FFT, GPGPU

1. Introduction

Process-based geological models such as flume experiments Paola et al. (2009); Straub et al. (2009); Kim et al. (2010); Tal and Paola (2010); Paola et al. (2011); Paola (2000) and advanced computer simulations of flow and sediment transport Elias et al. (2001); Giri et al. (2008); Lesser et al. (2004) are now widely used to study the effects of geological processes in the sedimentary record. These models are known for providing more insight into physical realism compared to rule-based models Xu (2014); Lopez (2003a), and are the de facto standard for addressing fundamental questions in sedimentary geology. One of the major drawbacks with the application of process-based models in practice is that they cannot be easily matched with the data acquired after deposition such as drilled wells or geophysical data. This limitation is inherent to any and all forward models, which are fully determined given well-posed boundary conditions (e. g. sea level rise, sediment supply). Furthermore, process-based geological models are complex as demonstrated by Figure 1, demand superb modeling expertise, great amount of time (computational or laboratorial), and can be quite laborious to design Briere et al. (2004).

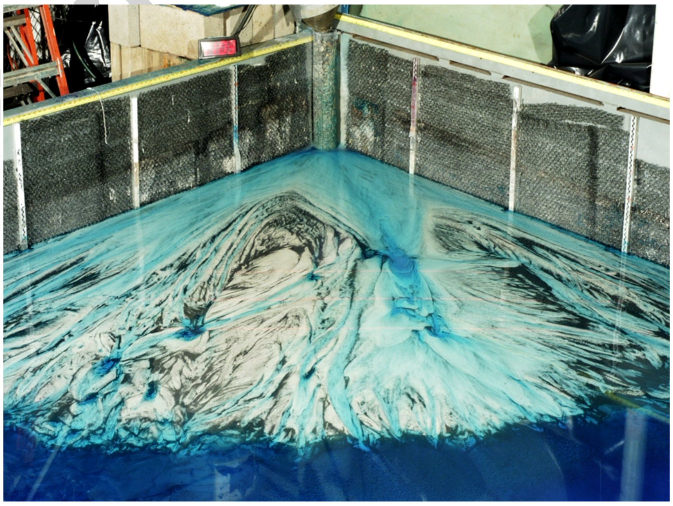

Figure 1: Flume experiment of a delta with low Froude number performed by John Martin, Ben Sheets, Chris Paola and Michael Kelberer. Image source: https://www.esci.umn.edu/orgs/seds/Sedi_Research.htm

In geostatistics, the process of conditioning 3D models to data has been actively investigated Matheron (1963); Mariethoz and Caers (2014). Although the research community has developed various modern algorithms in the past 15 years Strebelle (2002); Arpat and Caers (2007); Zhang et al. (2006, 2015); Honarkhah and Caers (2010); El Ouassini et al. (2008); Faucher et al. (2014); Tahmasebi et al. (2012); Mahmud et al. (2014); Yang et al.

[☆]Software is available at https://github.com/juliohm/ImageQuilting.jl.

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