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Karst simulation with Lindenmayer-systems and ODSIM

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Abstract

Karstic systems are geological structures that strongly impact underground flows. Despite intensive explorations by speleologists, they remain partially described as many conduits are not accessible to humans. Paleokarsts are buried karstic systems with a significant reservoir potential. But they are not easily identifiable on seismic images. In those contexts, a huge uncertainty subsists on the network location and the conduit geometry. Stochastic simulations help to better assess that uncertainty. The difficulty is to reproduce the system connectivity at different scales while integrating as much geological knowledge as possible without involving poorly constrained parameters (e.g. paleo-climate, boundary conditions...).

In this paper we propose to work on two aspects and scales of karstic systems. At large scale, we stochastically simulate karst network skeletons with a new method based on a formal grammar, the Lindenmayer-system. Based on an alphabet, an axiom and user-defined rules, the method puts together segments to build the network skeleton. The definition of proper rules and the introduction of karst-dedicated parameters generate curves reproducing the complex architectures encountered in those systems, mixing branchwork and anastomotic patterns.

At the conduit scale, we propose to build a 3D envelope around these skeletons with an enhanced Object Distance based Simulation Method. It uses a custom distance field from the skeleton which takes into account geological features influencing karstogenesis (horizons, faults or fractures). This controls the first-order shape of the conduits. It is then combined to a custom random threshold controlling finer-scale features of the conduits. This threshold is generated with several parameter values depending on the involved geological structures.

This workflow is demonstrated on a synthetic case, showing the potentialities of the approach at both scales. Results are encouraging and various improvements are in focus. Data conditioning, both to karst observations and local shape information has to be enhanced. The network simulation has the advantage to be grid-free, meaning that no background grid is needed to perform the simulation. Thus, it avoids the stair-step effect that can be observed in other techniques. On the opposite, the method used to simulate the conduit shapes relies on a grid, necessary to compute the distance fields and to perform the threshold geostatistical simulation. For detailed conduit geometry, the grid requires a high resolution, which impacts directly the computational efficiency. Finally, it would be interesting to test the approach on a real dataset and to develop a coupling with a flow simulator to evaluate the impact of the shape and of the network connections on the flow response.

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