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A multi-objective optimization framework to model 3D river and landscape evolution processes

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Water and sediment interactions shape hillslopes, regulate soil erosion and sedimentation, and organize river networks. Landscape evolution and river organization occur at various spatial and temporal scale and the understanding and modelling of them is highly complex. The idea of a least action principle governing river networks evolution has been proposed many times as a simpler approach among the ones existing in the literature. These theories assume that river networks, as observed in nature, self-organize and act on soil transportation in order to satisfy a particular "optimality" criterion. Accordingly, river and landscape weathering can be simulated by solving an optimization problem, where the choice of the criterion to be optimized becomes the initial assumption. The comparison between natural river networks and optimized ones verifies the correctness of this initial assumption. Yet, various criteria have been proposed in literature and there is no consensus on which is better able to explain river network features observed in nature like network branching and river bed profile: each one is able to reproduce some river features through simplified modelling of the natural processes, but it fails to characterize the whole complexity (3D and its dynamic) of the natural processes. Some of the criteria formulated in the literature partly conflict: the reason is that their formulation rely on mathematical and theoretical simplifications of the natural system that are suitable for specific spatial and temporal scale but fails to represent the whole processes characterizing landscape evolution.

In an attempt to address some of these scientific questions, we tested the suitability of using a multi-objective optimization framework to describe river and landscape evolution in a 3D spatial domain. A synthetic landscape is used to this purpose. Multiple, alternative river network evolutions, corresponding to as many tradeoffs between the different and partly conflicting optimality principles proposed in the literature, are computed by evolutionary multiobjective algorithm. Generated landscapes and their river networks are compared with the ones observed in nature through state of the art indicators, and visualized with erosion-deposition contour maps in order to make the comprehension easier.

Preliminary results show that multiobjective frameworks allow powerfully comparing how different optimality principles affect the simulation of landscape evolution and river organization. These findings prove that the single criteria proposed so far in literature can describe only part of the landscape evolution processes and that more comprehensive optimality criteria need to be proposed in order to prove that least action principle drives river network formation and to use this knowledge to simulate river and landscape evolution.