An Adaptation Of Response Surface Methodology To Explore Equifinality In A Numerical Landscape Evolution Model

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Abstract

Background and aims

Since the late 1980s, geomorphologists have developed various numerical computer models to simulate landscape evolution. An advantage of these models is that they allow exploration of different theories about landscape processes and past landscape change. This assists in attempts to falsify specific hypotheses derived from the theories. A major difficulty with such models, however, lies in finding correct values for the empirically-derived parameters used in the simulations. These values have to be derived from field data or, more often, model calibration. Whichever method is used, there is no formal process for choosing a parameter's value, and the resulting uncertainty means that the value may lie at any point within a given range. There are typically many such parameters in a landscape evolution model, and this raises the possibility that different combinations of parameter values will generate similar output from the model. This phenomenon is called *model equifinality*. A major degree of model equifinality is problematic because it implies the model is ambiguous, and therefore difficult to falsify. This in turn hampers the development of more complete theories of landscape processes and evolution. Although the potential for equifinality in complex models of this type has long been recognised (for example Beven, 1996), its extent in a landscape evolution model has not been quantified before. In this research, we seek to quantify the extent to which one landscape evolution model, taken as an exemplar, may generate equifinal results. We also consider how areas in the parameter space producing these results may be predicted.

Research strategy

The overall research strategy is similar to the optimisation and exploration techniques used in response surface methodology. Multiple simulations are performed, based on different parameter values sampled from the overall parameter space. Metrics, representing descriptors of the landscape simulated at 100,000 years of elapsed time, are extracted from the output and compared. Multiple regression techniques are used to derive equations which approximate the form of the metric's response to variations in the sampled parameter values. The equations are then used to predict, for each metric, which parameter value combinations are equifinal. The accuracy of each prediction is tested by running simulations to compare the model's output with the prediction. This procedure is repeated in an iterative process, so that patterns of near equifinal output are revealed, and quantification of equifinal emergent behaviour may be attempted.

Landscape setting and parameter sampling method

The landscape evolution model selected for use in this study is GOLEM (Tucker and Slingerland, 1997). Each simulation is initialised with a digital elevation model, taken from a catchment (c. 40 km^2) in the Oregon Coast Range of the USA. Although GOLEM may be run by varying twenty or more parameter values, this is an impractically large parameter space to explore. To make the search for equifinality more tractable, therefore, we have focused on just ten parameters, which between them cover the dominant processes in the chosen landscape setting. An initial set of simulations is run to sample the effects of these parameters on the model's output. The initial sampling design is a Box-Wilson, central composite design, incorporating a resolution *V*, 2^{10-3} fractional factorial (Wu and Hamada, 2000). It is believed that this is the first time a methodology of this kind has been attempted in a geomorphological modelling study. By our results, therefore, we hope to be able to comment on both model equifinality, and the effectiveness of this strategy in seeking to quantify and predict it.