Project title: Hybrid stochastic forecasting models for dynamic threshold determination
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Discipline: Statistics
Research area/keywords: Combining forecasting models, Copula based dependence models, Neuro-Fuzzy modelling, Safety factor in mining
Suitable for: Full time applicants

Project background and description:
This project aims to investigate stochastic models for the assessment of threshold values in time series accounting for exogenous factors. In particular, we will be using measurements from piezometers and prisms to predict certain geological forces. Piezometers and prisms are sensors widely used in mining structures, such as open-pit mines and tailing dams, to measure underground water pressure and slope inclination of deposited soil. Those measurements are used in the calculation of safety factors in mining. Low safety factors are associated with potential slope breaks that may cause structural damage and an accident. Currently, threshold values for those measurements are subjectively assessed by geological experts. The determination of threshold values are based on underground soil maps built from the sampling of geological variables (such as cohesion, friction angle and specific weight of soils) as well as on measurements from piezometers and prisms. Those assessments are largely based on the assumption that ground properties hardly change in time. In many cases however this assumption is too strong to hold.

In this project, the combination of probability distribution functions (obtained from simulations based on the measurements described above as well as on soil properties) will be used to determine the distribution of safety factors, and thus, estimate the probability of safety factors becoming too small. Inversely, given such probabilities, associated water pressures and structural soil displacements, and hence dynamic thresholds for the sensors, will be determined.

Initially, the WARIMAX-GARCH models of Correa et al. (2016) will be used to forecast slope inclinations and water pressures with precipitation measurements as exogenous variable. WARIMAX-GARCH models are appropriate for filtering both auto-regressive and frequency patterns from a time series but not non-linear patterns (such as those associated with local volatilities induced by anisotropic soil). Neuro-fuzzy (and possibly other) models for non-linearities will also be investigated here. Both the WARIMAX-GARCH and the Neuro-fuzzy models will then be combined into a hybrid forecasting model similarly to Zhang (2003) that combined neural networks with ARIMA models, and to Faria and Mubwandarikwa (2008) who proposed a geometric combination for dynamic models. From the hybrid forecasting distribution, time dependent geological properties can be simulated via Copula
based models. The distribution of safety factors may then be obtained (e.g. as in Cho, 2007) and, based on input values of failure probabilities, future thresholds for prisms and piezometers can be estimated.

The main expected contributions of this project are twofold. First, from a more theoretical standpoint, algorithms of the type proposed by Correa et al. (2016) and Zhang (2003) will be extended with the use more modern forecasting techniques. Secondly, from a more pragmatic point of view, the application of those forecasting techniques to systematically estimate dynamic thresholds from available data should provide an effective contribution to safety in mining and help prevent accidents such as a tailing dam failure.

Background reading/references