Aggregated Shapley effects from an acceptance-rejection sample: application to an avalanche model

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Abstract:

Avalanche flow dynamic models depend on poorly known inputs (e.g., friction parameters, initial conditions corresponding to the avalanche release) [2]. The outputs of these models are commonly both functional (e.g., the velocity and snow depth of an avalanche in different points of a discretized path) and scalar (e.g., runout distance). These models are employed for land-use planning as far as for the design of defense structures. Thus, it is required to assess the impact of the uncertainty of the input parameters on the outputs, and this is what sensitivity analysis aims at. So far in the avalanche field, few sensitivity analyses have been performed.

The aim of this work is to identify the most important inputs in an avalanche model. For the sensitivity analysis field, the main novelty of this application is the particular structure of avalanche model outputs. Indeed, the functional outputs have a high number of zeros corresponding to the zones where there is no avalanche. To be coherent with the application, only the non-null values should be used in the estimation. Therefore, the outputs are sampled with an acceptance-reject algorithm which induces dependent inputs. Due to the dependence, traditional sensitivity measures (such as Sobol' indices) lose their convenient interpretation.

The Shapley effects, based on equitable allocation of the output variance, have been recently proposed as sensitivity measures [3]. In comparison to other usual measures, they are suitable even when inputs are dependent. For this reason, their use is appropriate to our untypical application.

Even if it is possible to estimate the Shapley effects of each output, they could be difficult to interpret and provide redundant information. In particular, if the output dimension is high. Following [1] in this work, we propose a nonparametric estimation procedure for what we call aggregated Shapley effects to quantify the uncertainty of models with dependent inputs and high dimensional outputs. It is well known that the estimation of Shapley effects has a high computational cost. Thus, we also propose to reduce the output dimension. This task is achieved by using principal components analysis. The accuracy of the aggregated Shapley effect estimation as function of the sample and basis sizes is also analyzed. Our procedure is illustrated with a typical avalanche path from the French Alps.

References

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[3] A. Owen. Sobol' indices and shapley value. *SIAM/ASA Journal on Uncertainty Quantification*, 2(1):245–251, 2014.

Short biography – I'm a third year PhD student. I have an engineering Mathematics degree from the Escuela Politécnica Nacional (Ecuador) and a master's degree in Applied Mathematics from the University of Grenoble. My doctoral project is about the sensitivity analysis and the Bayesian calibration of avalanche models using data of high spatio-temporal resolution. This project is founded by OSUG@2020 and the CDP-Trajectories framework.