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Metamodelling approaches to sensitivity analysis with dependent inputs

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Sensitivity analysis is a relatively well-developed field which offers a range of established approaches for quantifying the contribution of the uncertainty in model inputs and assumptions to the uncertainty in the model outputs. A large majority of these methods still rest on the assumption that the inputs are independent; however, in the last decade, attention has gradually increased to the more complicated case in which inputs are not independent, and a number of alternative methods have been proposed. Of these methods, a number of caveats are apparent. First, methods may be limited to particular types of joint input distribution, such as joint Gaussian. Other methods may only consider linear pairwise dependence (correlation) and neglect the more general case where dependence can be of any order and nonlinear. Finally, many methods require the parametric specification of the joint input distribution, whereas in practice this may often not be known.

In this work, alternative approaches are explored. The first is a regression-based approach, which uses nonlinear Gaussian process regression to model the dependence structure between inputs, and requires no parametric specification of input distributions; only a sample. This is a nonlinear and full-order extension of existing work which allows estimation of first-order variance based sensitivity indices, decomposed into contributions due to dependence with other inputs, and independent effects. The Gaussian process regression also allows confidence intervals to be put on estimated indices. Finally, a further step is proposed in which the total effect indices can also be estimated, using a metamodeling approach and only using the sample of the given data.

The second approach follows similar lines, but uses a Bayesian implementation of a polynomial chaos expansion, and explores different transformation functions for obtaining dependent variables from independent ones, and vice versa. This approach can also work with given data. The two approaches are compared.