Preliminary Analysis of the Morris Method for Identifying Influential Parameters

by

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Introduction

Performance assessment of the geologic disposal of radioactive waste is an inherently complex problem involving significant uncertainties. To ensure that the disposal of the waste is safe over long time periods, performance assessments that involve uncertainty and sensitivity analysis are conducted using a mathematical model which stochastically samples uncertain parameters over their range of plausible values. Analysis of the sensitivity of the performance measure to these parameters is conducted with the goal of reducing the list of parameters to a manageable level so that more attention can be given to the most influential parameters driving the system performance.

A variety of techniques, such as scatter plots, differential analysis, regression methods, and response surface techniques are available to quantify the uncertainty and sensitivity in complex models[1,2]. These techniques are either cumbersome (e.g., scatter plots) or require that the relationship between input and output variables be linear or quadratic[2] (i.e., response surface techniques). This paper describes the implementation of an experimental design based method, referred to as the Morris method[3], to conduct sensitivity analysis for a model with a large number of sampled parameters. Additionally this paper presents the sensitivity measures used in the study and associated parameter transformations for the best representation of the overall problem. The method employs a sequence of randomized one-factor-at-a-time numerical experiments such that changes in the output corresponding to these isolated parameter increments are unambiguously attributable to the specific change in the input. The number of model computations needed to conduct the sensitivity analysis is proportional to the number of parameters under investigation.

Application Problem

Implementation of the Morris method technique for a complex waste disposal system is modeled using the Total-System Performance Assessment (TPA) code[4] developed by the Center for Nuclear Waste Regulatory Analyses (CNWRA) and the Nuclear Regulatory Commission (NRC) to estimate the uncertainty in the post-closure performance of the proposed high-level waste (HLW) repository at Yucca Mountain (YM) over long time periods. The TPA code estimates dose to a receptor group for specified time periods at designated receptor locations by modeling many processes including degradation or disruption of the engineered barrier system (EBS), release of radionuclides from the EBS, transport of radionuclides from the EBS through the natural system, and the exposure dose resulting from the radionuclides. The code contains nearly 850 input parameters out of which 246 are sampled from specified probability distribution functions.

Results

A measure of parameter influence on the model output is what Morris (1991) calls the elementary effects, ($\triangle y/\triangle x_i$), where $\triangle y$ is the change in the output variable y for a given change $\triangle x_i$ in the sampled input parameter, x_i. The one-factor-at-a-time design matrix facilitates isolating the elementary effects for each parameter. The mean and standard deviation of the elementary effects obtained from the TPA runs are plotted and analyzed graphically as shown in figure 1 for a 10,000 yr simulation period. The number printed next to each point is an input parameter identifier. The top ten influential parameters, selected on the basis of their displacement from zero mean and standard deviation of the elementary effects, are also identified with their associated abbreviation. Out of 246 parameters, 171 are clustered around the zero mean and zero standard deviations neighborhood, indicating that changes in these parameters did not significantly alter the output variable and thus are not considered influential. There are several points that lie distinctly apart from the cluster of zero mean and standard deviation. Parameters AAMAI@S, Fow*, FOCTR, WP_Def%, have high mean and low standard deviations, indicating these parameters have a significant influence on peak dose. Parameters FOCTR-R and FOCR-R have large mean and standard deviation suggesting that they possess strong nonlinear effects and/or have strong interactive effects with other parameters on the output.

Conclusions

The Morris method used to identify the most influential parameters of a complex, highly nonlinear computer model has the advantage that the method does not require the use of any simplifying assumptions about the mathematical form of the computational model. Because the number of model simulations needed in this method is proportional to the number of parameters under investigation, it is an economical sensitivity analysis technique. The method also provides a visual screening method for isolating influential parameters for models that have many sampled parameters. Analyses to date suggest that while the method may not be adequate for generating an absolute ranking of the parameters based on their sensitivity estimate, it works well as a screening tool for identifying sensitive parameters.

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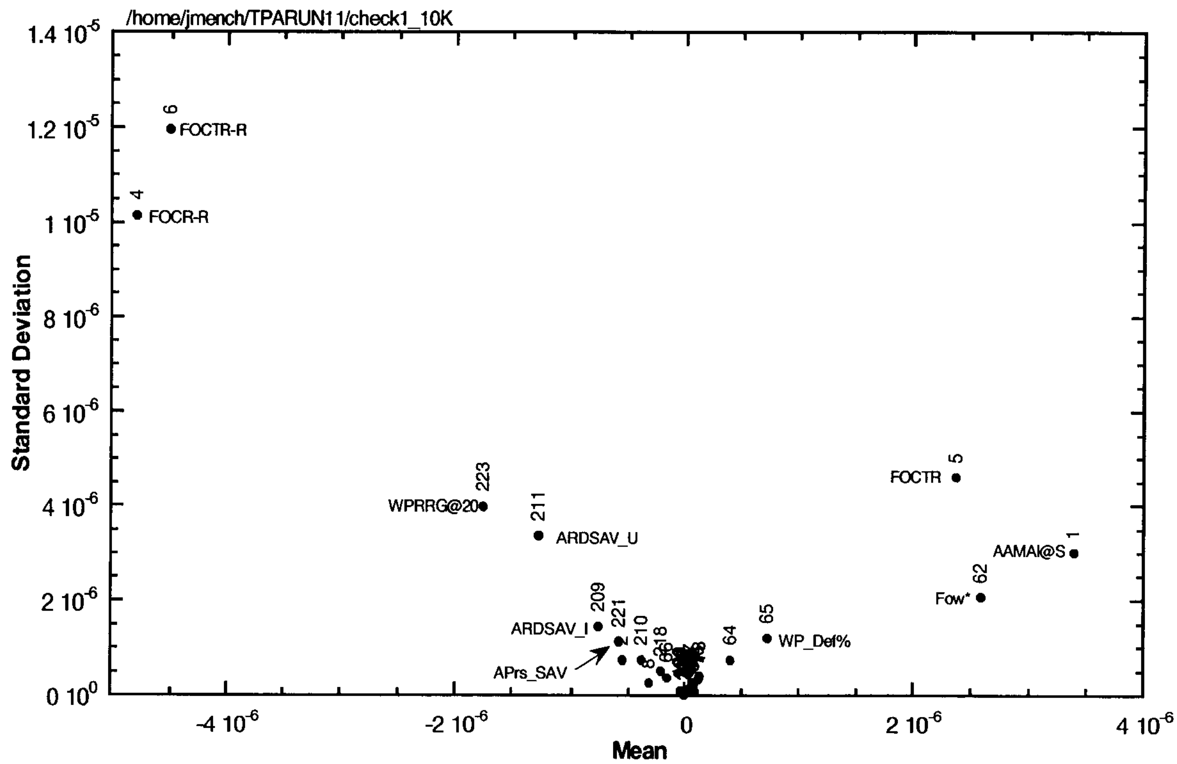

Figure 1. Estimated means and standard-deviations of the distributions of elementary effects. Results are presented in this figure for the normalized input parameters for the base-case data set with a time period of interest of 10 kyr.