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FReET: Software for Uncertainties Propagation

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Abstract **-** The purpose, concept and main software features and stochastic methods implemented in FReET software are briefly summarized. Efficient techniques of employing stochastic simulation methods were combined in order to offer an advanced tool for the probabilistic assessment of any user-defined engineering problem.

Keywords**:** Uncertainties propagation, statistical analysis, sensitivity, reliability, Monte Carlo simulation, Latin hypercube sampling, small-sample simulation

1. Introduction / Motivation

Probabilistic techniques are used in various fields of engineering, and they offer advantages over the more traditional deterministic methods. In deterministic methods therefore, part of the information available is not inherently exploited, but for instance, safety factors are considered, leading usually in this way to conservative and therefore safe answers in design or assessment. By contrast, in probabilistic methods, these uncertainties are directly utilized fully as inputs. Less conservative answers are therefore obtained as uncertain reality is simulated.

Efficient methods for statistical, sensitivity and reliability assessment were implemented in FReET software [1], [2]. Attention is given to those techniques that have been developed for the analysis of computationally intensive problems; nonlinear FEM analysis being a typical example. The possibility of "randomizing" of any engineering computational tasks in the sense of the Monte Carlo type of simulation is enabled. The stratified simulation technique Latin hypercube sampling is used in order to achieve variance reduction of the estimated outputs at a given (usually small) number of simulations. A robust technique to impose statistical correlation based on the stochastic method of optimization called simulated annealing has been proposed [3]. Methodology and software tool are prepared for a routine application. Software have been used in many practical applications mainly for concrete structures reliability analysis [4] and they are continuously improved by implementation of new state of art methods.

2. Purpose / Concept

The program FReET is designed as user-friendly tool for simulation of random variables X_i according to their probability distribution functions (vector $\mathbf{X}$) and to process numerically user-defined response/limit state function $g(\mathbf{X})$. Uncertainties propagation concept is illustrated in Fig. 1 by "input and output" software windows. Generally following types of analyses can be performed:

- Statistical analysis – program estimates mean value, standard deviation (statistical moments) of g, and shows the suitable probability density function of g.
- Sensitivity analysis – program calculates the level of influence of random variables X_i on $g(\mathbf{X})$.
- Reliability analysis – program calculates the failure probability (and/or reliability index) p_f, as probability that g is smaller than zero.

The concept of program FReET is characterized by the aim to provide a very practical software tool, which can be used and handled very easily – in a straightforward feasible way. Software is optimized with an emphasize on interactivity and user-friendliness.

The user has several options to define the analyzed function g. The complexity of the task is decisive for the selection of an appropriate interface:

- Closed form (direct), using the implemented Equation Editor (simple problems).
- Numerical (indirect), using a user-defined DLL function that can be prepared in practically any programming language (C++, Fortran, Delphi, etc.).
- General interface to third-party software using user-defined *.BAT or *.EXE programs based on input and output text communication files.

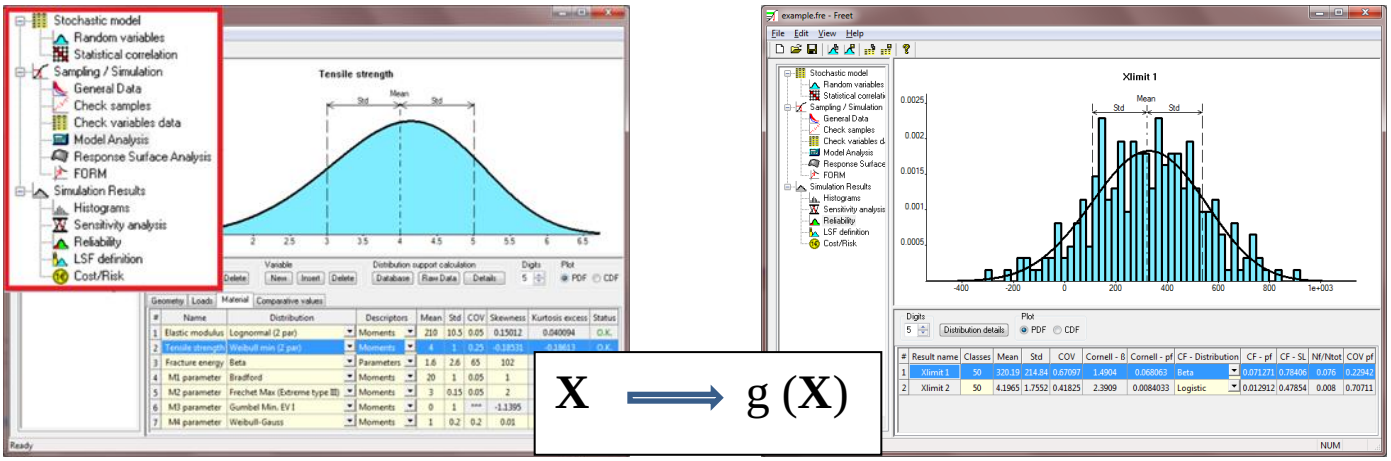

Fig. 1: Uncertainties propagation concept in FReET: “Random variables” window - INPUT (above); “Reliability” window with empirical histogram - OUTPUT, (below)

3. Features / Methods

State-of-the-art probabilistic algorithms are implemented in FReET to compute the probabilistic response and reliability. FReET is a modular computer system for performing probabilistic analysis developed mainly for computationally intensive deterministic modeling and the running of user-defined tasks/subroutines. The main features of the software are:

3.1. Stochastic model (inputs)

Authors The fundamental part of the software is the user-friendly handling of inputs – basic random variables and statistical correlation. The main features are:

- A friendly Graphical User Interface (GUI).
- 30 probability distribution functions (PDF), mostly 2-parametric, some 3-parametric, two 4-parametric (Beta and normal PDF with a Weibullian left tail).
- Unified description of random variables with the optional use of statistical moments or parameters or a combination of moments and parameters.
- PDF calculator.
- Extreme value distributions and order statistics for any available parametric distribution.
- Statistical correlation (including a weighting option).
- Categories and comparative values for PDFs.
- Visualization of random variables, including statistical correlation in both Cartesian and parallel coordinates.

3.2. Results (outputs)

Papers should use 11-point Times New Roman font. The styles available are bold, italic and underlined. It is recommended that any text in the “figures” should not be smaller than 10-point font size.

The assessment of outputs (the results of Monte Carlo-type simulation) consists of:

- Statistical moments and histograms of output variables.

- Sensitivity analyses.
- Reliability estimates (failure probability and/or reliability index) by various simulation and approximation methods.
- Limit state functions visualization.
- Parametric studies.
- Cost/Risk assessment.

3.3. Probabilistic techniques

Both standard and advanced statistical, simulation and reliability techniques are implemented:

- Crude Monte Carlo simulation.
- Latin Hypercube Sampling (3 alternatives).
- Hierarchical Latin Hypercube Sampling (extension of sample size).
- First Order Reliability Method (FORM).
- Curve fitting for PDF.
- Simulated Annealing employed for correlation control over inputs.
- Bayesian updating.
- Response surface.
- Importance sampling around mean values.

4. Conclusion

The presented software tool may be applied in the advanced design/assessment of engineering tasks, when making decisions about alternatives, when searching for optimum life-cycle cost solutions, and in cost-effective decision-making processes.

Acknowledgements

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