# EE-UQ Application Summary (V3.4.0)

The Earthquake Engineering with Uncertainty Quantification (EE-UQ) application creates and launches simulation workflows to assess the response of a structure subjected to earthquakes. The application provides: 1) methods to represent the seismic hazard at a site through a set of acceleration time histories, 2) multiple approaches to create a numerical model of the structure, and 3) various options to perform the numerical simulation of the response. Both deterministic and probabilistic simulations are supported. In probabilistic simulations, random variables can represent uncertainties in the seismic event, the structural model, and the numerical simulation solver. These uncertainties are automatically propagated through the simulation to arrive at a probabilistic description of structural response. Probabilistic simulation results can be further processed to perform sensitivity analysis or train surrogate models.

USE CASES

Select Ground Motions and Run a Probabilistic Assessment
To represent a given seismic scenario, the ground motion record selection application can choose acceleration time histories provided by the user or the PEER NGA West 2 database. OpenSees structural models defined in Tcl or Python can be imported. The user can also define random variables in the structural model and can specify which response quantities to record. Simulations for hundreds of ground motions and model realizations are facilitated by seamlessly running the analyses through DesignSafe.
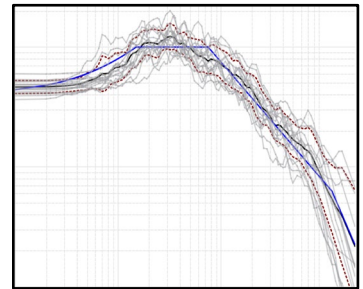

Generate OpenSees Structural Models
Four tools are available to generate OpenSees models based on user-defined building information. The options range from user-defined high-level building characteristics (number of stories, structural system), to detailed structural information (frame geometry, material properties, load parameters). The former is used to create idealized MDOF models, while the latter supports the generation of steel and concrete frame models.
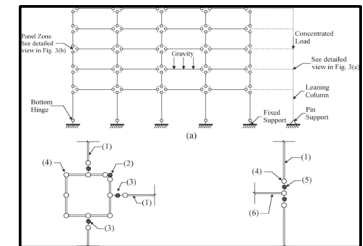

Run a Parametric Study with Ground Motions and Structures
Any input parameters for the ground motions or structural model can be defined as random variables, which are assigned random values within a predefined domain. Parametric analyses are performed by sampling the input space for parameters of interest and performing simulations for multiple realizations. Built-in sensitivity analysis methods offer further insight into the influence of the selected inputs on the simulated structural response.
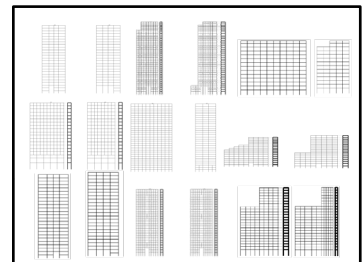
Develop Structural-Response Surrogate Models
Built-in uncertainty quantification engines can train surrogate models that aim to reproduce the results of complex numerical simulations at a fraction of the original computation time. For example, if the user has a high-fidelity OpenSees model of a structural system, EE-UQ can assist in selecting a robust set of ground motions, preparing high-quality training data, and developing an appropriate surrogate model.
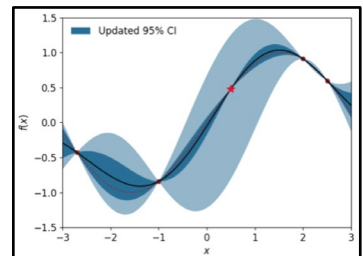
CURRENT CAPABILITIES

Ground Motion: Returns ground motion records in SimCenter's JSON format. Each record is a time history of a seismic event in one or more dimensions (typically the two primary horizontal directions). The following options are available:

- User provided ground motion time histories (in PEER or SimCenter format).
- Stochastic generation of acceleration time histories from earthquake rupture characteristics.
- Selection of ground motion records from the PEER NGA West 2 or a user-specified ground motion database to match a target spectrum or to efficiently fill a pre-defined intensity-measure space.
- Simulate free-field shaking based on specified bedrock motions and soil column information using OpenSees-based site-response analysis.

Structural Model: Defines the structural modeling approach and returns the scripts required to perform the response simulation. One or more models can be assigned to a workflow. Using more than one model allows for benchmarking and epistemic uncertainty analysis. The following options are available:

- User-specified OpenSees model in Tcl or Python format.
- User-specified Python script that prepares a structural model and performs the response simulation.
- Automatic generation of an idealized Opensees shear column model from basic building information.
- Automatic generation of a steel or reinforced concrete OpenSees frame model from detailed design information.
- Import a user-specified structural-response surrogate model.
- A multi-model approach, which allows user to specify multiple combinations of the above options.
- Multi-fidelity Monte Carlo routines to utilize lower cost computational models along with higher fidelity models to reduce computational time while preserving accuracy.

Response Simulation: Defines the analysis options that will be used to perform the numerical simulation, e.g. time integration strategy, convergence criteria, and damping options. The user-specified modeling tool is used to perform the simulation and collect the requested response quantities.

Uncertainty Quantification: Samples the prescribed random input variables and obtains realizations of the outputs by executing the workflow with each input realization from the generated sample. The underlying UQ engines let you leverage the following techniques in your research:

- Forward propagation: Define a set of random input parameters and perform Monte Carlo simulations to obtain a corresponding sample of output parameters.
- Sensitivity analysis: Measure the influence of variability in each input on the uncertainty of outputs.
- Reliability analysis: Algorithms to estimate the probability of exceeding a failure threshold.
- Surrogate models: Generate training data and develop surrogate models using Gaussian Process and Probabilistic Learning on Manifolds techniques.

UPCOMING CAPABILITIES

- Domain Reduction Method to incorporate physics-based ground motion simulation output (e.g., output from SW4, SCEC BP) into the workflow. (Sep 2024)

MORE INFORMATION

The software application, examples, and Information about previous releases can be found in the documentation accessible from the EE-UQ website at: https://simcenter.designsafe-ci.org/research-tools/ee-uq-application/