Reliability, sensitivity, and optimization-enabling technologies

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Introduction

- OpenSees reaching maturity for dynamic, nonlinear, coupled SFSI simulation
- Research emphasis on PBEE evaluation of transportation network components
- Challenges
  - Sensitivity to model and design parameters, particularly for nonlinear response
  - Reliability/risk assessment under prevailing uncertainties
  - Extend design optimization to include more complex objectives

Illustrations

- Sensitivity
  - E.g., sensitivity of nodal displacements to constitutive model parameters: $\frac{\partial \mathbf{u}}{\partial \Theta}$
- Reliability
  - E.g., probability of nodal displacement exceeding threshold: $p_f = \int_{\Omega} f(\Theta) d\Theta$ $\quad \Omega = \{g(\Theta) \le 0\}$ $\quad \Omega = \bigcup_k \bigcap_{j \in c_k} \{g_j(\Theta) \le 0\}$
- Optimization
  - E.g., structural properties minimizing nodal displacement p_f: $\mathbf{y} = \arg\min\{p_f(\Theta) | \theta_1 > 0, a < \theta_2 < b, h > 2L\}$

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Research Needs

- Development, maintenance, and extensibility of OpenSees framework
- Requires software abstractions for reliability/ sensitivity/optimization consistent with OO design
- Interaction with FE and analysis domain
- Open-source and OO paradigm that will allow end-user contribution/extension
  - No code duplication
  - No changes to abstract and base classes
- Build on previous work (Der Kiureghian, Haukaas, etc.)

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Proposed changes

- Correcting existing modules not functioning
  - Roadmap for re-implementing deprecated modules
- Syntax overhaul
  - Separation of Tcl implementation of LSF from base class
- Parameterization
- Gradient, Hessian, and LSF redesign
- Analysis module class hierarchy (e.g., findDesignPoint), data storage, others …
- Coordinating with Conte/UCSD optimization framework

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Parameterization

- Abstract Parameter class
- Concrete parameters can be positioned in FE, reliability, optimization, etc. domains
  - Pointers to FE model parameters, as well as FE response
  - Random variable and design variable parameters
  - Pointers to Reliability model (e.g., distribution parameters), as well as reliability results (e.g., pf)
  - Pointers to User/Scripting language variables

Syntax, Non-Tcl, etc.

- PerformanceFunction abstract or container class
  - LimitStateFunction, ObjectiveFunction, ConstraintFunction, GradientFunction are derived
  - Interfaces directly with FunctionEvaluator
- FunctionEvaluators no longer perform parsing
  - TclFun, MatlabFun, PythonFun, etc…
- For example, a Tcl PerformanceFunction:
  - limitStateFunction 3 "1.0+sqrt(\$par($parTag))"
- Parameter will dictate evaluator and gradient actions

Gradients

- No parsing in gradient classes
- No difference between OpenSeesGradG, FiniteDifferenceGradG now
- Only implicit and explicit gradients, as defined by parameters
- Option for analytic gradient, specified in GradientFunction
- Need similar abstraction for Hessian

Schedule

- Phase I
  - Immediate changes to get major existing reliability modules working
  - Syntax and input file data flows revised for future class changes
  - Document changes in cooperation with UCSD
  - Original target date: OpenSees Days 2010
    - New target date: end of October
- Phase II
  - Re-engineer classes & inheritance as discussed (parameter, gradient, functions, etc.)
  - Attempt to maintain methods from Phase I
  - Target date: summer 2011

Thank You!

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