Evolutionary Methodologies for Aseismic Design and Decision Support

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ABSTRACT

Evolutionary methods hold significant promise as an excellent framework for the development of a new class of decision support tools toward earthquake hazard mitigation. A general evolutionary framework is developed for the computational design and retrofit of building structures. To understand the behavior of complex adaptive systems, genetic algorithms are employed for the discrete optimization of passively damped structural systems. The overall methodology is developed and several model problems are examined.

Decisions about enhancing seismic safety in critical facilities requires more than engineering choices about which technology is most appropriate. Such decisions are made in the context of organizational goals and strategy, financial capacity, choices about how safe is safe enough, and driving forces in the social, economic, and political environment. The system dynamic behavioral models of an acute care hospital is developed. Different policy scenarios and earthquake scenarios are input into this model. The cost-benefit effects and some other socio-economic impacts are analyzed.

BACKGROUND

- Complex adaptive systems
  - Originally formulated by Holland (1975)
  - Involve the complicated nonlinear interaction of many components or agents, which Aggregate in a hierarchical manner in response to an uncertain or changing environment
  - Genetic algorithms
    - Holland’s work (1962, 1975) provided the development of genetic algorithms
    - Effective for finding robust solutions to combinatorial problems in the presence of environmental uncertainties.
- System dynamic model
  - Founded by Forrester (1961)
  - Practical, operational model with interdisciplinary ties
  - Decision-making model

OBJECTIVES

The objectives of this research are:

- Develop an automated system that can evolve robust designs based upon nonlinear transient dynamic response of the structure and passive dampers, while accounting for the inherent variability of the seismic environment
- Develop system dynamic behavioral models of organizational decision making about enhancing seismic safety for acute care hospitals. The platform integrates state of the art understanding of structural response, alternative means for mitigating the risk, normative decision-assisting models, and behavioral models of organizational choice and decision processes.

METHODS & RESULTS

- Engineering -> Evolutionary Aseismic Design & Retrofit
  Example: Twelve Story Steel Frame w/Discontinuity at 7th Story, located in Memphis, TN
  Lumped parameter structural model; Base structure (T=2s)
  Potential retrofit with all damper types; Story drift and acceleration limits imposed

- Sociotechnical -> Evolutionary Decision Support
  Stella® 7.0: Model Formulation and Validation
  Qualitative method of ODE: Stability Analysis

CONCLUSIONS

The evolutionary methodology for aseismic design and retrofit is robust. It consistently produces very good aseismic designs in uncertain environments, provided each structure experiences sufficient sampling of ground motions. The framework is general and applicable for multi-hazards (seismic, wind, blast, ...).

The system dynamic approach can satisfy many conditions for modeling a complex, dynamic and interdisciplinary system. System dynamic models can show the decision making process at work and help the decision makers to address issues of disaster mitigation. The methodology also enhances the interdisciplinary perspective and dialogue between engineering and social science researchers and practitioners.

ACKNOWLEDGEMENTS

Program area: Seismic Retrofit of Acute Care Facilities
Task number: 042010
Principal investigator: Gary F. Dargush
Acknowledgements: Multidisciplinary Center for Earthquake Engineering Research
National Science Foundation, New York State