Evolutionary Methodologies for Aseismic Design and Decision Support

G.F. Dargush[1] , Y. Hu[2]

1 Professor, Dept. of Mechanical and Aerospace Engineering, University at Buffalo
2 Graduate Research Assistant, Dept. of Civil, Structural and Environmental Engineering, University at Buffalo

ABSTRACT

One of the primary objectives of the overall earthquake engineering research program is to contribute toward the development of disaster-resilient communities. As a result, there is a general need to model, understand and ultimately direct the behavior of a wide variety of complex multi-scale systems. For example, within the context of a critical care facility, these not only include the structural and non-structural systems that shape the physical environment, but also the organizational systems that define the social and economic climate. Clearly, the problem does not end at the scale of a single hospital. By expanding our view, we can recognize that local communities and large corporations need to make decisions affecting the performance of a system of critical care facilities. At the regional level, one can argue that public policy and resource allocation should be based upon the behavior of systems of systems. Additionally, at each level, there is uncertainty, ambiguity and risk, along with a temporal dimension that must be considered. Evolutionary methodologies may be ideally suited to study and to provide guidance for many of these tasks. Here we concentrate on two aspects of the overall problem, namely, aseismic design and retrofit decision support and organizational decision support. In addition, we attempt to create a theoretical and computational framework that may have applicability for complex decision-making in general.

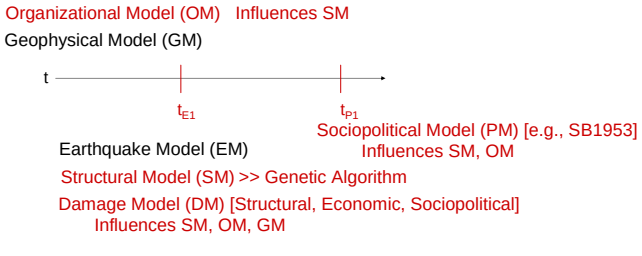
BACKGROUND

- 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 decision-making model with interdisciplinary ties

OBJECTIVES

The objectives of this research are:

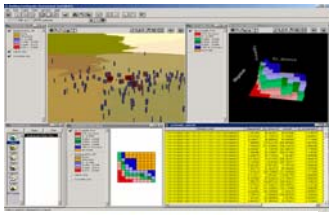
- Develop an automated system that can evolve robust designs based upon nonlinear transient dynamic response of the structure and passive dampers, while accounting for the inherent variability of the seismic environment
- Develop system dynamic behavioral models of organizational decision making about 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.
- Find an optimized and most robust combination of policies and retrofitting strategy using genetic algorithms.

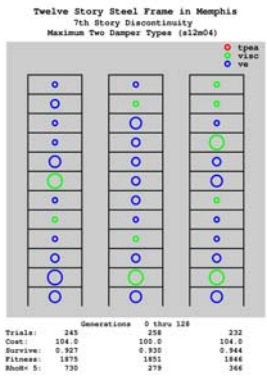


METHODS & RESULTS

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 two damper types; Story drift and acceleration limits imposed



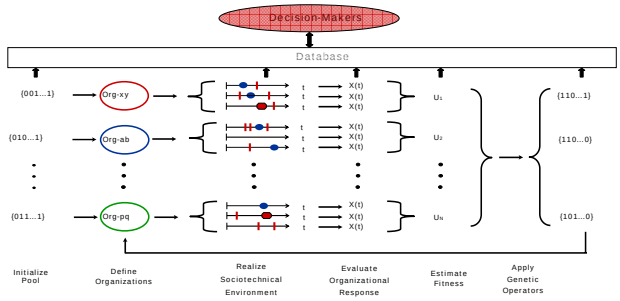


Sociotechnical -> Evolutionary Decision Support

System Dynamics Model Formulation and Validation
Genetic Algorithm: Policies Optimization

Genetic Code (18-bit design descriptor): ***aabbcc dd ee ff gg hh ii***

aabbcc: Policies regarding retrofitting
dd: Policies regarding B&E investment rate
ee: Policies regarding Patients vs. B&E ratio
ff: Policies regarding B&E investment
gg: Policies regarding Employees hiring rate
hh: Policies regarding P/E target ratio
ii: Policies regarding Employees hiring criterion



CONCLUSIONS

A general evolutionary framework has been developed to provide support for complex decision processes. Within the aseismic design and retrofit decision support domain, we present a computational approach based upon genetic algorithms that has significant potential. The system is able to discover robust designs in an uncertain seismic environment. In addition, the algorithms scale favorably with increasing problem size and are naturally parallel.

Beyond the engineering aspects of the mitigation problem are many associated socioeconomic issues that must enter into the decision-making process. Consequently, we focus on developing evolutionary formulations for decision support toward seismic risk reduction in critical care organizations. This new approach has considerable potential to provide guidance at the level of a single critical care facility and for regional planning of critical care networks.

ACKNOWLEDGEMENTS

Multidisciplinary Center for Earthquake Engineering Research
National Science Foundation, New York State