

A Basic Framework for Intelligent Civil Infrastructure Systems

Project Summary

The objective

By quantifying qualitative information in a form amenable to integration with a self-updating statistical analysis system, this proof-of-concept research produces, validates and delivers a platform independent suite of open ended computer programs, for generic infrastructure management.

The Method

Quantitative directive and numerical reliability indices from design documents and published sources, for physical infrastructure systems, subjective opinion and individual judgment, and bodies of laws and policies are collected and cataloged to construct a fuzzy logic-based probabilistic computational environment. The numerical representation of each variable contains the respective lower and upper bound congenial with the interval arithmetic construct of computer algebra. Fuzzy logic also allows frequency distributions within such uncertainty intervals. Critical principal values of correlation matrices identify potential injurious events according to extreme value statistics. Bayesian updating (in the integral form) for a very large number of independent variables allows the computer program to learn from discrepancies between predictions and observations. Based on rarely occurring patterns in lengthy combinations of simple features, the program seeks extreme events that escape conventional data mining.

Intellectual Merits — a novel paradigm: synthesizing numerics with subjective expertise

1. A synthesis of planning policies and computer mathematics yields a generic management software.
2. A computer-understandable and -manipulatable environment harnesses the experience of designers and management agencies in tracking and reporting the temporal sequence of a project.
3. The decision analysis program seamlessly integrates extreme value statistics with Bayesian updating of reliability based solutions, thus enhancing the conventional notion of machine learning.
4. Actions based on the continuously updated information are broadcast.
5. Exhaustive searches are carried out so as not to overlook any inadvertent extreme event. The notion of 'performance index,' akin to a probability measure with tolerance, introduces an objective quantification of the severity of an event through the complete combination of all crucial information.
6. The application domain of fuzzy logic is enhanced in this holistic characterization of system performance by integrating in a single database: (a) quantitative design specifications; (b) qualitative text-based policy statements; and (c) bodies of laws related to human experiences.
7. Any generic infrastructure threat mitigation is handled as an ongoing dynamic process that automatically trigger pre-planned rescue and evacuation strategies.
8. The research team interacts with the School of Social Work, Public Health, Law and Journalism to initiate long term NSF research to mitigate impending natural and man-made catastrophes.
9. The team presents the prototype at national and international conferences. All research materials (*e.g.* computer programs, reports and articles) are published and distributed without restriction.

Broader Impacts

1. The methodology is applicable to a wide range of problems including emergency management and disaster prevention. It also provides the primary framework for the emerging discipline of intelligent civil infrastructure.
2. It promotes innovative micro-electronic devices for practical applications in security enhancement.
3. Results from this pressing and socially beneficial research enhance future mitigation and reconstructions by preparing citizens to interact with civic authorities and relief agencies.
4. New classes of data — (a) sensor: chemical, biological, nuclear; (b) identification: face and biometric; (c) intelligence: friendly foreign agency, neighborhood awareness — are explored, as the core technology meets new societal challenges such as early warning and emergency rescue systems.
5. Experiences of government agencies (city, state and federal) are synthesized with that of citizens.
6. K – 12 students are trained for evacuation. Seniors in assisted living and care centers participate in rescue and evacuation exercises. An internet based seminar course trains undergraduate and graduate students how to incorporate human responses alongside constraints from design codes.
7. Gender balance and geographical diversity are addressed in offering training to students.