Sabbatical Report

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The following is a report of efforts undertaken during the spring semester 2006. The report is not in chronological order, but is organized by type of effort. My sabbatical plan is attached for reference.

Graduate Course Software

I converted Fortran software (no graphics) to MATLAB software (typically with graphics) for CE5241 *Structural Dynamics I*, CE5242 *Structural Dynamics II*, and CE5243 *Probability and Reliability for Civil Engineers*. I wrote some new MATLAB programs that used graphics to help students understand the material in these courses. The primary goals of this portion of the sabbatical was to develop software to aid in teaching graduate courses and to better learn MATLAB in preparation for writing computational intelligence software. The following programs were written and validated.

CE5241 and CE5242 – Structural Dynamics I and II

- Linear forcing function method (conversion with new graphics)
- Linear acceleration method (conversion with new graphics)
- Stodola's method [matrix iteration] (conversion with new graphics)
- Response spectra for a rectangular forcing function using Duhamel's integral (conversion with new graphics)
- Response spectra using the linear forcing function method (new with graphics)
- Graphical demonstration showing the dynamic motion of a column-mass system subjected to a user defined forcing function (new with graphics)

CE5243 – Probabilistic Analysis and Reliability in Civil Engineering

- Advanced first-order reliability method (conversion)
- Monte Carlo simulation to determine probability of failure (conversion)
- Monte Carlo simulation to generate a data set from a user defined function of random variables (conversion)
- Probability plotting technique for fitting distributions to data (conversion with new graphics)
- Software to plot probability density functions and cumulative distribution functions to show effect of changes in distribution parameters (new with graphics)

Computational Intelligence Software

I developed computational intelligence software using MATLAB, including genetic algorithms, particle swarms, artificial neural networks, and agent models. I had to learn each computational

intelligence technique before I could develop the software. The software developed using the computational intelligence techniques is shown below.

Genetic Algorithms

- A few binary and integer-value genetic algorithm (GA) programs were written to learn the basic process
- A real-value GA program that performs maximum likelihood estimation for 2-parameter probability distributions
- Simple truss optimization using real-value GAs
- Determination of terms in Markov probability transition matrices using real value GAs
- Other real-value GAs were written for artificial neural net (ANN) training. See below.

Particle Swarms

- A particle swarm program that performs the advanced first-order reliability method for a single limit state function
- A particle swarm program that performs the advanced first-order reliability method for multiple limit state functions—necessary for system reliability analysis
- Determination of terms in Markov probability transition matrices using particle swarms
- Particle swarms were also used to train ANNs. See below.

Artificial Neural Nets

- Artificial neural nets (ANNs) with one hidden layer were developed that learned various benchmark functions in order for me to learn the techniques and pitfalls encountered in training ANNs. The ANNs were trained using GAs, particle swarms, and back propagation. For the ANNs I examined, particle swarms proved to be the most robust method.
- An ANN with two hidden layers was also developed.
- A single hidden layer ANN was developed that predicts the mode of failure for a steel-doweled wood connection.

Agent Models

- A few versions of the Schelling segregation model were written in order to learn first-hand some of the difficulties involved in writing agent models.

Papers, proposals, and reviews

Papers:

- Drewek, M. W. and Bulleit, W. M. "Agent-based modeling of terrorism within a community environment," Submitted to the ASCE *Journal of Infrastructure Systems.*
- Bulleit, W. M. "Reliability of Wood Connections Designed Using LRFD from NDS-2005," to be published in the proceedings of and presented at the World Conference on Timber Engineering 2006 to be held in Portland in August 2006.

Proposals and Pre-proposals:

- Li, Y. and Bulleit, W. M. "Performance-based engineering methodology for multi-hazard risk assessment and mitigation," submitted to the Army Corps of Engineers, $259,319.
- Bulleit, W. M. and Li Y. "Probabilistic Modeling of Snow Loads including the Effects of Wind," preproposal submitted to the Cold Regions Research and Engineering Lab.

Reviews:

- Reviewed the book manuscript: *Snow Loads: Guide to the Snow Load Provisions of ASCE 7-05* by O'Rourke and Wrenn for ASCE.
- Reviewed a book proposal, *Structural Steel Design: A Practice-Centered Approach,* by Abi Aghayere & Jason Vigil for Prenctice-Hall.
- Reviewed a paper manuscript, "Exploratory study of small timber trusses constructed with through-bolt and cross-pipe heel connectors," by Eckelman, Haviavora, and Erdil for the *Forest Products Journal.*
- Reviewed a research proposal submitted to the Center of Excellence for Rural and Intermodal Transportation, "Application of structural reliability to optimize benefit/cost for timber railroad bridges."

Further Comments

Two items described in the sabbatical plan did *not* occur: (1) The course that Mary Durfee and I had taught in spring 2005 was not repeated in spring 2006 due to scheduling difficulties, and (2) an NSF Human and Social Dynamics Proposal that began in November 2005 fell apart in January due to lack of interest among important team members. By the time it fell apart, there was no longer time to try to pull together a team, which by necessity would have had to include investigators from outside the University.

The number of computational intelligence techniques I was able to learn and software I was able to write far exceeded the amount I expected to accomplish when I wrote the sabbatical plan.

Attachment

Sabbatical Plan

For the past 23 years, my primary research area has been in wood engineering with an emphasis on structural reliability applications in wood engineering. Structural reliability is the application of probabilistic methods to safety analysis of structural systems. Structural reliability analysis is one decision tool that assists engineers in the design of safe and economical structures. Over the last 2 to 3 years, my research interests have been evolving toward issues related to other types of tools that can assist engineers in the decision making process. I became one of the principal investigators on a proposal to NSF on the use of an agent-based approach to modeling the impact of bridge failures on two communities separated by a river. Although the project was not funded, agent based modeling looked like a powerful tool for decision support. But the agent based approach is just one of many methods that fall under the rubric of *computational intelligence.* Computational intelligence is the general subject to which I want to direct my present and future research efforts.

From September 1998 to August 2004, I was the Associate Chair of the Department of Civil and Environmental Engineering, including responsibility for managing the change to semesters and the Department assessment process. During that time, I taught at least 2 courses per semester (or quarter) and spent a year as Chair of the Provost Search Committee. This load did not allow me reasonable blocks of time for scholarly activity, particularly making a significant change in my research direction. My goal is to use the proposed sabbatical to help me jump start my move in the new research direction.

My sabbatical plan is to spend the spring semester of 2006 in the Houghton area studying literature, writing computer programs, and performing other work applicable to research in computational intelligence. Specifically, I'm interested in three overlapping areas: agent-based modeling, artificial neural networks, and genetic algorithms. The objective of the sabbatical is to become familiar enough with the three areas, both the literature and coding of the processes, to allow me to write better proposals than my present knowledge level, obtained in fits and spurts, allows. Thus, one goal of the proposed sabbatical will be to develop at least one computer program in each of the above three areas or one or more codes that combine two or more of the areas; for instance, develop a neural net that is trained using a genetic algorithm. The purpose of writing computer programs is to better understand the issues behind each of these types of modeling, more than can be learned simply by reading the literature. Another goal of the sabbatical will be to write a proposal to NSF related to computational intelligence that I will submit in the fall of 2006. I propose to remain in the Houghton area for the sabbatical for a number of reasons. First, I have access to a cabin where I can spend most of my days. The seclusion of the cabin will allow me to focus on the literature and the programming. Both of these jobs require large blocks of time free from interruption. Second, I am advising a PhD student who has an NSF graduate fellowship to study terrorist attacks using agent based modeling. His fellowship began in September 2004 and continues until August 2007. He and I are already working on papers related to his research and I will write one paper with him during the sabbatical. Third, in spring 2005, Dr. Mary Durfee and I are teaching a 1-credit directed research course on computational social science, which relates to agent-based modeling and

other techniques. The students in the class will each choose a project of their own and develop a computational model. The class will meet once a week to discuss issues related to computational social science and the students' programming efforts. The class will be more research than teaching. My goal for spring 2006 is that Dr. Durfee and I, and possibly others, will do a similar course, which will help me develop the ideas that I will be working on during the sabbatical. Last, I will have access to the capabilities of the Department, faster computers than I will use at the cabin and copying facilities. My objective is to have no teaching (as I said above, the directed research course is basically research) and no service. The focus of this sabbatical is *research in computational intelligence*.

In summary, the goal of the proposed sabbatical will be to help me jump start my move in a new research direction. During the sabbatical, I will produce a few computer programs in agent-based modeling, neural networks, and genetic algorithms; a paper written with my PhD student; and a proposal to NSF. My expectation is that the semester-long sabbatical also will allow me to develop paper and proposal ideas that will lead to more papers and proposals over the year following the sabbatical.