CIMMS
Focused Workshop on Uncertainty in Engineering Design

Abstracts for Scheduled Talks

Winnett Lounge, Caltech

May 23, 2002

9:00 - 9:45

Trade-Offs, Strategies and Negotiation in Engineering Design

Erik K. Antonsson

Department of Mechanical Engineering
California Institute of Technology
Pasadena, California 91125

Abstract

Engineering design requires information to be processed and decisions to be made in the presence of significant levels of imprecision and uncertainty. Traditional approaches to engineering have focused on analyzing precise information. Our research has introduced a formal method for representing and manipulating imprecise information in engineering design to enable designers to compare the performance of design alternatives, even at the highly imprecise preliminary stages. Additionally, formal methods for trading-off multiple incommensurate aspects of design performance, and for negotiating among multidisciplinary members of design teams have been developed. The approach is related to, but distinct from, game theory and economic decision-making. These methods, including some of the computational aspects, will be described and illustrated with an example from industry.

10:00 - 10:45

Innovation and Uncertainty Systems Engineering and R & D Management: A Manifesto for Industrial Change

Carl N. Nett
Clas A. Jacobson
Mark M. Myers

United Technologies Research Center
East Hartford, CT 06108

Abstract

This talk presents an overview of innovation in industrial R&D and the role that uncertainty identification and management play in the innovation process. Innovation is a key component in the growth of a company — innovation is essential to drive new product and process growth. Innovation is presented in this talk as an output that is the result of combining an idea with an implementation to generate value to the parent company. The ideas associated with innovation can be generated in systematic ways and the generation of a rich set of concepts is critical to the innovation process. Equally critical in the innovation process is the management of uncertainty associated with the concepts and this talk presents the management of uncertainty in the setting of systems engineering. Systems engineering is the management of product and process development from concept to value addition. The identification and management of interfaces — both programmatic as well as technical — especially in the innovation cycle as the product moves from concept to preliminary design — must include uncertainty across the interfaces. This talk presents these concepts with reference to the case of building systems — an infrastructure that is becoming of more importance to both commercial as well as military customers due to health concerns — and is an excellent example of both innovation as well as systems engineering and uncertainty management.

11:00 - 11:45

Modeling of Complex Systems

Igor Mezic

Department of Mechanical and Environmental Engineering
University of California, Santa Barbara

Abstract

Many of the component-level physical and system-level network phenomena used in advanced industrial products are complex in nature, on surface contradicting the apparent simplicity and robustness of the product's engineered performance. If that performance needs improvement for competitive or regulatory reasons, the process of development commonly requires detailed understanding of some of the underlying physical and system properties. But, this often does not mean that computing from the first principles is going to solve the problem. In many cases, due to the development timescales involved or the complexity of the component/system involved, reduced order modeling is a must. And the question of model validation necessarily arises. I will present a framework for model validation, developed in collaboration with the United Technologies Research Center, that stems from dynamical systems and ergodic theory ideas. The framework is built on the following ideas:

1. It is often not necessary and/or possible to perform a detailed, trajectory-wise comparison of the model and physical data it is attempting to represent. A statistical comparison (comparison of "emergent" or "engineered" properties) might be more appropriate.
2. Statistical comparison of performance of dyamical systems in the sense of invariant measures still might not be enough. Harmonic (spectral) analysis needs to be developed.
3. The formalism needs to allow for a rigorous choice of scales over which the validation is performed.

The developed framework for model validation is a hybrid of statistical, dynamical systems and multi-scale thinking. I will present an example in which we identified parameters for a stochastic, 2-degree of freedom dynamical system model of a combustion process. I will argue that sometimes even very complicated processes can be modeled effectively with a small number of degrees of freedom if the dynamics of neglected scales is replaced by a stochastic process.

Model validation/identification is naturally related to model uncertainty. I will discuss how the above ideas can be extended to provide a method for treating model uncertainty within dynamical systems theory.

11:45 - 12:30

Uncertainty Management in Automobile Design

Robert V. Lust

Vehicle Analysis and Dynamics Lab
General Motors Research & Development Center
Warren, Michigan

Abstract

The characterization and management of uncertainty in engineering design is critical to the rapid and successful execution of the vehicle development process. In support of a vehicle program, engineers struggle as they try to design to uncertain requirements and provide decision makers with credible, timely and robust estimates of a multitude of design related vehicle performance attributes. At the same time, the vehicle program managers are challenged with the task of integrating uncertain information across a large number of functional areas, assessing program risk and then making program level decisions that ultimately constrain the engineering design activity.

In this presentation I will briefly discuss the vehicle development process and my view of the role of engineering in support of that process. I will then discuss the importance of understanding and managing uncertainties; specifically as this relates to setting vehicle functional requirements and assessing designs relative to those requirements. I will present examples of how we can use formal approaches to engineering design that allow us to manage some common types of uncertainty and discuss some of the limitations of these methods. Finally, I will conclude by discussing a number of important challenges in this area and proposing some potential areas for collaborative research.

14:00 - 14:45

Uncertainty and Design Margins in Space Systems Design

Daniel P. Thunnissen

Division of Engineering and Applied Science
California Institute of Technology
Pasadena, California 91125

Abstract

A method for propagating and mitigating the effect of uncertainty in conceptual level design via probabilistic methods is described. The goal of this research is to develop a rigorous foundation for determining design margins in complex multidisciplinary systems. The current deterministic method of uncertainty mitigation in complex multidisciplinary systems is reviewed. As an example, the investigated method is applied to the conceptual design and development of a composite overwrapped pressure vessel. For the pressure vessel example, margins for mass, schedule, cost, and risk form a set of tradable system-level parameters. The variables involved in the design and development of the pressure vessel are classified and each is assigned an appropriate probability density function. To characterize the resulting system, a Monte Carlo simulation is used. Results of this simulation are combined with the risk tolerance of the decision maker(s) to guide in the determination of margin levels. This procedure is repeated until the decision maker is satisfied with the balance of system-level parameter values. Application of this method to the pressure vessel example yielded important differences between the calculated design margins and the values typically assumed in conceptual design. The ultimate goal of this research will be a method for propagating and mitigating the effect of uncertainty that can be applied to any complex multidisciplinary engineering system.

15:00 - 15:45

Subdivision Surfaces for Multiresolution Modeling, Simulation, and Design

Peter Schröder

Department of Computer Science and
Applied and Computational Mathematics
California Institute of Technology
Pasadena, California 91125I

Abstract

Much of today's engineering design practice is hampered by many, largely incompatible, tools for geometric modeling, physical simulation and design. Finding unifying principles, representations, and computational algorithms provides one avenue to better this situation.

In this presentation I will discuss results of a recent project by a group of Caltech faculty, postdocs, and students (mRSED: Multiresolution Simulation for Engineering Design) and cover the use of subdivision surface representations as a basis for such an integrated treatment. Subdivision surfaces offer many computational advantages in free-form surface modeling ranging from adaptive level of detail to deep connections with wavelet representations. The underlying basis functions are also ideally suited as a foundation for finite element treatments of the mechanical response of thin-shells.

These techniques are part of a broader program aimed at developing efficient representations and algorithms for the manipulation of digital geometry. They will be essential in hierarchical (multiscale) modeling, design, and simulation efforts that are required to track and deal with uncertainty, especially those that involve many scales. I will conclude with a discussion of the exciting opportunities that present themselves.

16:00 - 16:45

Uncertainty in Modeling Diabetes

Dave Polidori

Entelos Inc.

Abstract

Modeling complex diseases such as diabetes involves uncertainty arising from several sources, including parts of the biology that are still unknown, conflicting data, individual variability, and modeling simplifications. Developing models of complex diseases and using them in pharmaceutical R&D requires a clear understanding of these uncertainties and methods of analysis for determining the effects of these uncertainties on model predictions. I will discuss some of the approaches we have taken to address these problems.