ARC Collaborative Research Seminar Series
Winter 2006

February 23rd, Thursday (9:30-11:00am)
University of Michigan, Lurie Engineering Center, Level 3, Johnson Rooms B & C

Alternative Methods for Relibility-Based Robust Design Optimization
Including Dimension Reduction Methods

Presenters:
K.K. Choi, The University of Iowa
Nick Vlahopoulos, The University of Michigan
Matt Castanier, The University of Michigan

In the first part of this presentation, recent advances in reliability-based robust design optimization (RBRDO) will be presented. The objective of RBRDO is to minimize the product quality loss function subject to probabilistic constraints. Since the quality loss function is usually expressed in terms of the first two statistical moments, mean and variance, many methods have been proposed to accurately and efficiently estimate the moments. Among the methods, univariate dimension reduction method (DRM), performance moment integration (PMI), and percentile difference method (PDM) are recently proposed methods. In the presented work, estimation of statistical moments and their sensitivities are carried out using DRM and compared with results obtained using PMI and PDM. In addition, PMI and DRM are also compared in terms of how accurately and efficiently they estimate the statistical moments and their sensitivities of a performance function. In this comparison, PDM is excluded since PDM could not even accurately estimate the statistical moments of the performance function. Also, robust design optimization using DRM, PMI, and PDM are carried out and the results are compared. Several numerical examples are used for the two comparisons. The comparisons show that DRM is effective when the number of design variables is small and PMI is effective when the number of design variables is relatively large. For the inverse reliability analysis of reliability-based design, the enriched performance measure approach (PMA+) is used.

In the second part of this presentation, efficient structural simulation and analysis technologies that are being developed to support RBRDO will be discussed. The generation of fast running models based on principal component analysis and metamodel theory will be presented. These fast running models can be utilized for model updating in nonlinear dynamic applications and for error estimation. In addition, a parametric reduced-order modeling method for quick assessment of the effects of component design parameter changes on the structural response will be presented. Applications to vehicle models will be shown to illustrate the performance of the approach.

March 9th, Thursday (9:30-11:00am)
University of Michigan, Lurie Engineering Center, Level 4, GM Room

Presented by Thrust Area 2:

Task Coordination and the Virtual Driver: Integrating Task Planning and Cognitive Simulation with Human Movement Models
Matthew P. Reed, Omer Tsimhoni, University of Michigan
The Human Motion Simulation Laboratory at the University of Michigan has developed a suite of algorithms, known as the HUMOSIM Framework, to simulate human motions in digital human modeling environments. As the low-level motion modules have become more mature, we have directed our attention to the higher-level planning and organization of motion. Progress over the

past six months has included a resource-based model of hand-eye coordination for sequences of manual and visual tasks. The model generates realistic coordination of head/neck, torso, and upper-extremity motions as a function of task requirements.

Active Biodynamic Human Response Model Including Feedback Control
Kevin A. Rider, Bernard J. Martin, The University of Michigan

Visual and somatosensory feedbacks are involved in pointing movements. As the fingertip approaches the target, vision becomes the dominant feedback mechanism by which the master controller of the central nervous system ensures the successful completion of the reach. Conversely, the absence of visual feedback yields decreases in endpoint accuracy. An ongoing series of studies is investigating the influences of vehicle motion on human reaching and pointing, to reveal movement strategies used in visually-occluded and visually guided reaching tasks. Terrain-induced ride motion, transmitted to the operator through the vehicle structures and seat, induces a biodynamic response of the human body.

Visual occlusion decreases the ability to make rapid online compensatory movements, which results in initial radial deviations that are poorly correlated with radial dispersion at the target. Perturbations to rapid, visually-guided reaches are compensated on-line and result in poorly correlated endpoint dispersions, emphasizing the strong effect of visual feedback in temporally-constrained reaching tasks. In conditions where the vehicle is stationary (no vibration), these uncompensated, rapid reaches serve as estimates of the individual's intended trajectory. When ride motion is present, trajectories of rapid, visually-occluded reaches provide a measure of the natural biodynamic response of the cantilevered spine-arm-hand linkage. These intended movement trajectories and the biodynamic response (vibration feedthrough) are used to predict the effect of ride motion on rapid, visually-guided reaches. The biodynamic model including the task and ride motion parameters, also includes the visual and somatosensory feedback loops used to compensate for ride motion perturbations. Furthermore, some model parameters are determined by estimation of upper body impedance in postures similar between subjects of different sizes

Integrating Cognitive, Sensorimotor, and Biomechanical Models of Vehicle Occupants
Brent Gillespie, The University of Michigan

In this talk we will describe our initial efforts at integrating a computational cognitive model of the human driver with our biomechanical and sensorimotor models of reaching and manual control. We are interested in analyzing the performance of the driver and passenger at manual control, push-button, and decision making tasks as impeded by secondary tasks and vehicle motion. Such prediction capabilities will enhance human-centered design capabilities in software and test platforms that support the design of future military vehicles and human interface systems. We will feature work on models of biodynamic feedthrough and models of seated interactions with displays and controls that are parameterized on anthropometric measures to address improved design of control interface, seating, and restraint systems. We will also feature the integration of our work with existing models of human performance and biomechanics such as IMPRINT in use at ARL and AVB-DYN by Systems Technology Inc.

March 23rd, Thursday (9:30-11:00am)
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Presented by Thrust Area 1:
Progress Towards Integrated Vehicle System, Driver, and Environment Modeling, Simulation, and Control

LARGE-SCALE TERRAIN MODELING
Presented by David Page, The University of Tennessee

The main objective of this research is to address the U.S. Army need for improved soft soil traversing characteristics. This objective has three subtasks.

1. Collect data with video cameras and other sensors—mounted directly on vehicles—of tire-soil and vehicle-terrain interaction. Additionally, study and understand sensor suites and configurations necessary to provide appropriate data to meet Army needs.
2. Develop appropriate 3D reconstruction and data fusion methods to create 3D models of tire-soil and vehicle-terrain interactions.
3. Develop automated segmentation, data reduction, and analysis tools to facilitate understanding and evaluation of 3D modeling results.

CONTROL OF FUEL CELL POWER SYSTEMS
Presented by Denise McKay, The University of Michigan
We will summarize on-going efforts in developing a novel membrane-based humidifier designed to independently control temperature and humidity of a gas stream that feeds a fuel processor or fuel cell. We will also highlight some results from our work on FC electric architecture for APU and vehicle power applications.

ANALYSIS OF DRIVER PERFORMANCE AND BEHAVIOR USING THE ACAS DATABASE
Presented by Timothy Gordon, The University of Michigan
The focus of this project is on the analysis and modeling of human behavior related to erratic lane-keeping control. The study characterizes unintended road departures from analysis of large driving databases. A relevant driver control model is proposed and parameterized via system identification. The models are expected to support an accelerated development process for driver assistance systems, including for military applications.

DEVELOPMENT OF A VIRTUAL ENGINE SCALING MODEL FOR ENGINE-IN-THE-LOOP SIMULATION OF HYBRID VEHICLES
Presented by Hosam Fathy, The University of Michigan
The use of engine-in-the-loop (EIL) simulation to compare conventional and hybrid powertrains poses an interesting problem, namely, the difficulty of physically downsizing the engine for the hybrid powertrains. This talk will briefly present an algorithm for virtually scaling both a physical engine and its virtual drivetrain within an EIL setup to enable fair comparisons of conventional and hybrid propulsion options. The algorithm builds on the concepts of common platform design, geometric similarity, and approximate similitude, and will be demonstrated using a simple example.

April 13th, Thursday (9:30-11:00am)
University of Michigan, Lurie Engineering Center, Level 4, GM Room

Presented by Thrust Area 5

Update on Case Study:
A "System of Systems" Approach for Design (with Uncertainty) of Army Ground Vehicles
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**Optimal Design with Non-Normally Distributed Random Parameters,
Conditional Probability, and Joint Constraint Reliabilities:
A Case Study in Vehicle Emissions Regulations to Achieve Ambient Air Quality Standards**
Kuei-Yuan Chan, The University of Michigan

Making appropriate environmental policy decisions requires considering various sources of uncertainty. An air pollution example is formulated as a design optimization problem with probabilistic constraints, also referred to as reliability-based design optimization (RBDO). Environmental applications with a large number of constraints and significant model complexity present special challenges. In this work an efficient active set strategy is integrated with a reliability contour surface approach to solve probabilistic problems with non-normal variable probability distributions. Discrete random parameters, which result in Bayesian probability, are also present and they are incorporated using delta function approximations. Joint constraint reliability that considers satisfying all regulatory constraints is also discussed. A demonstration example of setting the optimal vehicle speed limit while maintaining high reliability for CO and NOx standards of a residential area near two highway systems will be presented.

Combined Design and Robust Control of a Vehicle Passive/Active Suspension
Sulaiman Alyaqout, The University of Michigan

In this talk we will introduce an approach that combines passive and active elements to improve the robustness of a vehicle suspension system with respect to a worst-case scenario. This integrated passive and active suspension approach leads to a coupled optimization problem that is often difficult to solve. To reduce the computational effort, a sequential strategy that optimizes the passive elements first, and then the active elements, is used depending on the strength of the coupling. The effect of level of uncertainty, tire stiffness, and unsprung mass parameters on this

coupling is then studied. Varying such parameters leads to establishing a relationship between coupling and robustness of the control system. This link between coupling and robustness can be utilized to aid the designer in assessing the parameters' influence on coupling and robustness. The resulting approach is shown to improve the robustness properties of the vehicle suspension system. We also show that, by varying the level of uncertainty parameter, the coupling between design and robust control tends to increase as the applied level of uncertainty increases. In addition, demanding more robustness for vehicle suspensions with harsh ride characteristics increases coupling much more rapidly compared to suspensions with soft ride characteristics.

April 27th, Thursday (9:30-11:00am)
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Presented by Thrust Area 4:

OPERAS Strategies for Military and Commercial Advanced Diesel Engines
Naeim A. Henein, Wayne State University

Characterizing the Effect of Diesel Engine Transients on Visual Signature
Jonathan Hagena, The University of Michigan

(no abstracts available)

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