ARC Collaborative Research Seminar Series
Fall 2009

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September 16th, Wednesday (9:30-11:00am)
University of Michigan, Lurie Engineering Center, Level 4, GM Room

Thrust Area 1 Presenting
Vehicle Parameter Identification for Safety and Mobility

Computational Approaches to Parameter Identification Using Polynomial Chaos
Emmanuel Blanchard, Corina Sandu, Adrian Sandu, Virginia Tech University

Many parameters in mechanical systems cannot be measured physically with good accuracy, which results in parametric and external excitation uncertainties. In this presentation we compare two new computational approaches for parameter estimation. The first approach is a polynomial-chaos based Bayesian approach in which maximum likelihood estimates are obtained by minimizing a cost function derived from the Bayesian theorem. The second one uses an Extended Kalman Filter (EKF) to obtain the polynomial chaos representation of the uncertain states and the uncertain parameters. The two methods are illustrated on a nonlinear four degree of freedom roll plane vehicle model, where an uncertain mass with an uncertain location is added on the roll bar.

Both approaches can work with noisy measurements and yield results close to the actual values of the parameters, except when different combinations of uncertain parameters lead to essentially the same time response than the measured response. In that case, the a posteriori probability densities of the estimated parameters obtained with the EKF approach cannot be trusted. The Bayesian approach identifies that problem since the Bayesian cost function has an entire region of minima, and can use regularization techniques to yield most likely values in that region based on a priori knowledge.

Progress towards Recursive Off-Road Vehicle Mass Estimation
Ben Pence, Hosam K. Fathy, Jeffrey L. Stein, The University of Michigan

This presentation is motivated by the need to determine the mass of off-road vehicles whose loading conditions vary significantly from one trip to the next. The online estimate is to be used by vehicle control strategies such as safety control and powertrain control strategies to improve passenger safety, reduce the likelihood of vehicle rollover, and improve vehicle performance. Existing sprung mass estimation strategies based on suspension dynamics require either suspension force actuation or prior knowledge of terrain characteristics. This presentation proposes three estimation methods, each of which is founded on a base excitation model of a vehicle suspension system. The base excitation formulation treats unsprung mass motions as measured base excitations, thus eliminating the need for ground disturbance measurement or suspension actuation. The proposed methods uniquely combine the base-excitation concept with recursive estimation strategies. These strategies include recursive least squares, recursive total least squares, and recursive polynomial chaos estimation. The presentation demonstrates the methods via computer simulations of quarter-car and half-car models. It concludes that each method may provide a potential solution for real-time, sprung mass estimation for off-road vehicles. However, in computer simulations, the polynomial chaos method calculates a less biased estimate than the recursive least squares and recursive total least squares methods.

October 14th, Wednesday (9:30-11:00am)

University of Michigan, Lurie Engineering Center, Level 4, GM Room

Thrust Area 3 Presenting:

Dynamic Kriging Method: A New Meta-Modeling Method for Simulation-Based Design Optimization

Liang Zhao, KK Choi, and Ikjin Lee
Department of Mechanical and Industrial Engineering, The University of Iowa

In recent years, meta-modeling has been widely applied to design optimization problems to build a surrogate model of computationally-intensive engineering systems. Kriging method has gained significant interests for developing the surrogate model due to its accuracy. However, traditional Kriging methods, including the ordinary and universal Kriging methods, use fixed polynomial basis functions to generate the mean structure, which might not reflect the nonlinearity of the systems. In this presentation, to fit the true model more accurately, we propose the Dynamic Kriging (D-Kriging) method, where the optimal mean structure is automatically determined by applying the genetic algorithm to the candidate basis functions based on a new accuracy criterion. In addition, a new sequential sampling technique that is based on the prediction interval of the surrogate model is proposed and integrated into the D-Kriging method. Numerical examples show that D-Kriging method can yield much more accurate results compared with traditional Kriging methods as well as other meta-modeling methods. Moreover, the prediction interval of the proposed meta-model will also be generated to provide the confidence level of the meta-model output in the simulation-based design optimization.

Multi-scale Simulations for Developing Light Weight Vehicles with Increased Survivability to Loads from Explosions and High Velocity Projectiles

Nick Vlahopoulos; University of Michigan

The U.S. Armed forces face the need for rapid deployment from the United States in order to engage regional threats decisively on a global basis. Size and weight are paramount factors for Army vehicles supporting this force projection structure. Lighter weight vehicles is an enabling factor for faster transport, higher mobility, fuel conservation, and a reduced ground footprint of supporting forces. At the same time high levels of protection must be offered by the vehicle to its occupants against combined loads from explosions and high velocity fragments and projectiles. Weight reduction and high levels of survivability are mutually competing objectives. Composite materials provide some of the most viable options for manufacturing such lightweight vehicles provided that they can offer the desirable level of protection. Multi-scale simulations are pursued in this project for designing such materials and for evaluating the overall vehicle survivability. The progress of this research up to date will be summarized in this presentation.

Sampling-based RBDO using Stochastic Sensitivity Analysis of Surrogate Model with Correlated Input Variables

Ikjin Lee, KK Choi, Liang Zhao, and Yoojeong Noh
Department of Mechanical and Industrial Engineering, The University of Iowa

This study presents a methodology for computing stochastic sensitivities with respect to the design variables, which is the mean value of the input correlated random variables. Assuming that an accurate surrogate model is available, the proposed method calculates the component, or system reliability, or statistical moments and their sensitivities by applying Monte Carlo simulation (MCS) to the accurate surrogate model. Since the surrogate model is used, the computational cost for the stochastic sensitivity analysis is negligible. The copula is used to model the joint distribution of the correlated input random variables, and the score function is used to derive the stochastic sensitivities of reliability or statistical moments. Merit of the proposed method is that it does not require the gradients of performance functions, which could be very well erroneous when obtained from the surrogate model, and the transformation from X-space to U-space. Since no transformation is required and the reliability or statistical moment is calculated in X-space, there is no approximation or restriction in calculating the sensitivities of the reliability or statistical moment unlike the First-Order Reliability Method (FORM). Hence, the design optimization using the proposed method yields a very accurate optimum design if the accurate surrogate model is used. Numerical results indicate that the proposed method can estimate the sensitivities of the reliability or statistical moment very accurately. Furthermore, the RBDO with the proposed method can find an optimum design accurately and efficiently when combined with a surrogate model. In conclusion, the proposed method is a good approach for problems where performance function gradients are not accurate or not available.

October 28th, Wednesday (9:30-11:00am)
University of Michigan, Lurie Engineering Center, Level 4, GM Room

Thrust Area 2 Presenting:

Model-Based Analysis and Classification of Driver Distraction under Secondary Tasks

Tulga Ersal, Helen Fuller, Omer Tsimhoni, Jeffrey L. Stein, and Hosam K. Fathy
University of Michigan

When driving a vehicle, military or civilian, drivers inevitably become involved in secondary tasks, such as interacting with in-vehicle information systems. It is well established in the literature that secondary tasks adversely affect driving behavior and performance; and being a major source of driver distraction, the cause for up to 80% of all accidents, they are a major safety concern. Previous research has focused on discovering the general trends by analyzing the average effects of secondary tasks on a population of drivers. This talk conjectures that there may also be individual effects, i.e., different effects of secondary tasks on individual drivers, which may be obscured within the average behavior of the population, and proposes a model-based approach to analyze them. Specifically, a radial-basis neural network based modeling framework is developed to characterize the normal driving behavior of a driver when driving without secondary tasks. The model is then used in a scenario of driving with a secondary task to predict the hypothetical actions of the driver, had there been no secondary tasks. The difference between the predicted normal behavior and the actual distracted behavior gives individual insight into how the secondary tasks affect the driver. It is shown that this framework can help uncover the different effects of secondary tasks on each driver, and when used together with support vector machines, it can help systematically classify normal and distracted driving conditions for each driver. This information could not only be used offline to achieve a safer design of in-vehicle systems or as an evaluation metric during driver training, but also online to enhance the performance of active safety systems. Thus, this work has a potential significant impact on driver safety in both military and civilian vehicles.

The Virtual Driver: Integrating Physical and Cognitive Models to Simulate Convoy Driving with a Secondary In-Vehicle Task

Helen Fuller, Matthew Reed, Yili Liu
University of Michigan

Driver distraction is a topic of increasing concern. Driver distraction can occur when a driver performs an in-vehicle task, such as tuning a radio, entering coordinates into a GPS system, or operating a communications device in a military vehicle. Most distraction-inducing activities have physical as well as cognitive components, so it is difficult to simulate them in the existing, predominantly cognitive, models of driving.

The goal of this project was to integrate a physical human model (HUMOSIM Framework running in the Jack human modeling environment) with a computational cognitive model (QN-MHP) to study complex human-machine interactions during driving. A driving simulator experiment was conducted to generate data that was used to tune and validate the integrated model. Men and women with a wide range of body size followed a lead vehicle that changed speed continuously as they entered information on a touch-screen display located in each of four positions. Driving behavior and secondary task performance results will be presented, along with strategies that subjects used to share resources between the two tasks. In addition, the modeling work performed to simulate the combined task will be discussed.

Biomechanical Model For Human Motion Simulation And Analysis Of Reach Performance Under Whole-Body Vibration Exposure

Heon Jeong Kim, Bernard J. Martin
University of Michigan

Vehicle vibration is a well-recognized environmental stressor that induces discomfort, health risks, and performance degradation of the driver or operators on board. More specifically, vibration that is transmitted by heavy transportation, construction, or military vehicles to the whole body of a seated occupant may significantly interfere with manual activities and compromise task performance.

The ultimate goal of this research is to develop an active biodynamic model of a seated human that can represent human movement dynamics and performance under whole-body vibration by integrating vibration characteristics of multi-body segments of the upper limbs when performing dynamic movements. Through a series of laboratory studies on the TARDEC Ride Motion Simulator, this research investigated the mechanisms of vibration transmission through a multi-body system of a seated human in various vibration conditions, identified reach kinematics of upper body joints in dynamic environments, and analyzed variations of vibration transmissibility affected by change of posture or coordination of movements.

November 18th, Wednesday (9:30-11:00am)
University of Michigan, Lurie Engineering Center, Level 3, Johnson Rooms B & C

Thrust Area 4 Presenting
Advanced and Hybrid Powertrains

Overview of Advanced and Hybrid Propulsion Research in TA4
Zoran Filipi (UM), Naeim Henein (WSU)

Comparative Analysis of Autoignition and Combustion Characteristics of JP8, Biodiesel and ULSD fuels
Naeim Henein (WSU)

Preliminary modeling of JP-8 Combustion: Evaporation effects
Aris Babajimopoulos (UM)

Fuel Properties Estimation from the Analysis of the Crankshaft Speed Variation
Dinu Taraza (WSU)

Vehicle Thermal Management System of Advanced Vehicles:
The Impact of Climate Control System
Dohoy Jung (UM-Dearborn)

December 9th, Wednesday (9:00-10:30am)
TARDEC, Warren, MI

Thrust Area 5 Presenting
Hosted by TARDEC at Warren, MI

Drop Tower Model Design Space Exploration and Representation
Steven Hoffenson

This study examines army vehicle design for blastworthiness, particularly through the design space exploration of a multi-body drop tower model. Drop towers simulate the vertical motion of the occupant compartment of a vehicle under attack from an underbody explosion, such as that from a land mine or an improvised explosive device (IED). Physical drop tower simulations are time-intensive and costly, and a computer model of the test bed has been constructed using MADYMO. This study implements the MADYMO model to understand the effects of varying occupant size, seat energy absorbing (EA) system properties, seat foam properties, and blast pulse on occupant injury. Three injury parameters in particular – upper neck axial force, lower lumbar axial force, and lower tibia axial force – have been found to cause the greatest injury to army vehicle occupants under blast loading, and thus they are studied as the outputs of the simulation model. A design of experiments (DoE) was conducted using full factorial and optimal latin hypercube sampling, and the results are used to train, validate, and test an artificial neural network surrogate model. For quick and user-friendly implementation of the metamodel, a graphical user interface (GUI) has been constructed as a stand-alone program for rapid assessment of seat designs for occupant safety. Future directions include modeling the relationship between vehicle weight and blast transmission to the occupant compartment, leading to a general bi-objective formulation to maximize both fuel economy and safety.

Managing Vector-Valued Coupling Variables in Electric Vehicle Powertrain System Optimization

Michael Alexander

Decomposition-based optimization strategies such as analytical target cascading (ATC) decouple system design problems, and the coupling variables communicated between subproblems are treated as decision variables in the optimization formulations. Although this increases the overall dimensionality of the problem, such a condition usually has negligible impact on computational expense when compared to directly solving the coupled system. However, if the coupling variables consist of infinite-dimensional quantities, such as response functions, implementing ATC may become computationally challenging. Discretization is typically applied, transforming infinite-dimensional variables into finite-dimensional ones represented as vectors. Nevertheless, because a large number of discretization points is often necessary to ensure a sufficiently accurate representation of the response functions, the dimensionality of these vector-valued coupling variables (VVCVs) can become prohibitively large for ATC optimization. It is therefore desirable to approximate the VVCVs with a reduced dimension representation that improves optimization efficiency while preserving sufficient accuracy. This study investigates two representation techniques, radial-basis function artificial neural networks and proper orthogonal decomposition, and implements each in an ATC problem formulation for electric vehicle powertrain system optimization. Specifically, both techniques are applied to VVCVs associated with motor boundary torque curves and power loss maps and are assessed in terms of dimensionality reduction, computational efficiency, and accuracy. Although the current study is based on a commercial vehicle application, it is expected that the acquired design knowledge will be directly applicable to future case studies involving military light-tactical vehicles (LTVs).

Sequential Optimization of Coupled Design/Control (Co-Design) Problems using Control Proxy Functions

Diane Peters

Many systems, including vehicles and robots, exhibit coupling between the object and the controller - the performance of the device itself may depend upon the controller, and the performance of the controller depends on the physical configuration of the device. In systems where the design and control are coupled, conventional sequential optimization does not typically generate the best solution; the solution found will be optimal for one objective, but not for the other. A simultaneous formulation will provide optimal solutions, but is far more complex. In this work, a modified sequential optimization formulation, augmenting the first objective with a term representing the ease of control of the system, is developed which produces near-optimal results with less computational effort than the simultaneous method. This work outlines the characteristics of an appropriate function, which is termed the Control Proxy Function (CPF). Problems that are amenable to solution with this method are discussed, with particular attention to mobile robots such as the Pacbot.

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