ARC Collaborative Research Seminar Series
Winter 2008

February 6th, Wednesday (9:30-11:00am)
University of Michigan, Lurie Engineering Center, Level 4, GM Room

Presenting:
Thrust Area 1 – Dynamics and Control of Vehicles

Stochastic Modeling of the Terrain Profile and its Impact on the Vehicle Response
Corina Sandu (Virginia Tech)

One fundamental difficulty in understanding the physics of the off-road traction and in predicting vehicle performance is the variability of the terrain profile. These operating conditions are uniquely defined at a given spatial location and a given time. It is not practically feasible to measure them at a sufficiently large number of points to be able to accurately represent the terrain in models, or to use all the data collected to recreate the terrain profile. This renders traditional analysis tools insufficient when dealing with rough terrain.

In this study, mathematical tools to quantify the impact of uncertainties in the terrain profile on vehicle mobility are developed. A polynomial chaos approach is used to reconstruct one-dimensional (along longitudinal direction) stationary and non-stationary terrain profiles. Also, an efficient mathematical method based on the Karhunen-Loeve expansion and the approach for 1-D stochastic terrain profile is developed to reconstruct two-dimensional (along longitudinal and lateral direction) terrain profiles. The proposed mathematical methods calculate the autocorrelation of terrain profiles, solve eigenvalues and eigenvectors of the autocorrelation function, and obtain the corresponding orthogonal random variables directly. The original terrain profile is reconstructed by Karhunen-Loeve expansion, requesting small a limited computational effort, without the need to verify the terrain data for Gaussianity, stationary, and linearity, and without the need to choose the order of the expansion and the corresponding fitting coefficient artificially. Promising simulation results based on experimental data are obtained using the proposed methods. The schemes to choose the number of eigenvalues and eigenvectors are discussed. The proposed mathematical methods can be used to simulate the terrain profile for on-road and off-road vehicle dynamics or robotic applications.

A short description of the soil testing capabilities at Virginia Tech will also be included. This part of the presentation will focus on the terramechanics rig built in the Advanced Vehicle Dynamics Laboratory, which allows indoor testing of pneumatic tires or other types of wheels on soft soil, ice, and hard surfaces.

Real-Time Adaptive Volterra Filter Characterization of MR Dampers
Steve Southward (Virginia Tech)
No abstract available.

On Modeling and Simulation of Terrain Profiles
Jingfeng Wei, T.C. Sun (Wayne State), D. Gorsich, M. Chaika and K. Alyass (TACOM)

(1) The goal of our reserach is to build computer models for existing terrain profiles by statistical methods and to use the models to simulate the terrain profiles in laboratories. We have data from 2 terrain profiles, Belgian Block and Perryman2, obtained by US Army at the Aberdeen Proving Ground in Maryland and the Yuma Test Facility in Arizona respectively.

(2) The Belgian Block profile can be modeled quite well by a Uniformly Modulated Process model

which is non-stationary but linear. The Peryman3 profile is Non-stationary, non-linear and non-Gaussian Whose structure is much more complicated than the Belgian Block profile. We propose 3 nonlinear models:

i) ARMA-GARCH Model
ii) TAR Model
iii) EMD-TAR Model.

In this talk we shall try to explain these models to people who are not specialized in statistics.

(3) One criterion used by statistcians to determine the fitness of the models to the actual data is to look at the behavier of their error sequences. Here the error sequence means the difference between the sequence of actual data values and the sequence of values computed from the models. If a model fits the data well the error sequence should be uncorrelated or it should be a white noise. According to this criterion all the 3 proposed nonlinear models fit well, it is hard to say which one is better. Therefore we Propose another criterion from the fatigue mechanics point of view that will help us to determine which model fits the terrain data best. We also believe that this criterion can provide us with another way of characterizing a terrain's roughness.

February 20th, Wednesday (9:30-11:00am)
University of Michigan, Lurie Engineering Center, Level 4, GM Room

Presenting:
Thrust Area 4 – Advanced and Hybrid Powertrains

Overview of ARC III Research at WSU and Biodiesel Combustion Characteristics
Prof. Naeim A. Henein

Piston Secondary Motions and Hydrodynamic Lubrication Regime In a Single Cylinder Internal Combustion Engine
Prof. N.G. Chalhoub

Unsteady Flow and Heat Transfer in EGR Cooler
Radu-Catalin Florea

Cooling System Architecture Design for FCS Hybrid Electric Vehicle
Dr. Dohoy Jung

March 12th, Wednesday (9:30-11:00am)
University of Michigan, Lurie Engineering Center, Level 4, GM Room

Presenting:
Thrust Area 3 – High Performance Structures and Materials

Predicting Effects of Component-Level Damage on System-Level Structural Response
Matt Castanier, University of Michigan

This presentation will cover recent research in modeling, simulation, and reanalysis techniques for predicting the structural dynamic response of a vehicle that has suffered damage in a component. Component-level damage cases of interest include a crack due to fatigue and local deformation due to blast/impact. When a component in a vehicle structure suffers damage, a model of the healthy structure may no longer capture the system-level response and/or the loading on the component from the rest of the structure. Furthermore, being able to model and reanalyze the response of the damaged structure has important applications to damage detection and condition-based maintenance. Examples include determining characteristic signals and/or sensor locations for detecting crack formation, predicting reliability under damage scenarios, and guiding repair methods. In this talk, modeling techniques being developed in the ARC for predicting the effects of component-level deformation and cracking on the system-level structural response will be presented. In addition, some other recent research efforts on simulating the nonlinear vibration of a cracked structure due to intermittent contact of the crack surfaces will be highlighted.

A Process to Reduce Vehicle Weight While Maintaining/Improving Performance and Reliability Requirements

KK Choi, University of Iowa

It is desirable to extend the life of Army ground vehicles since sustainment of the tactical and ground combat fleets is critical in long drawn out wars, which brings a number of challenges. Rapid deployability and mobility require lighter vehicle weights, whereas maintainability and sustainability require ultra-reliable vehicle components. Recent memos from the Assistant Secretary of the Army and the Commanding General of RDECOM indicated the need of Reliability Insertion in Army S&T Programs.

The challenge is that the weight-minimized vehicle structures would be much more susceptible to military operational and manufacturing variabilities and thus it would be more difficult to achieve ultra-reliability. The Reliability-Based Design Optimization (RBDO) method is an effective way to improve future designs by reducing weight, increasing the average life of parts subject to fatigue, and decreasing total lifecycle cost. It is envisioned that the methods and simulation tools developed in this project will be directly applicable to modeling and simulation for appropriate TARDEC ATO programs.

Currently, we are developing and implementing a simulation-based RBDO process using TARDEC HPC. Successful verifications and RBDO applications of three Iowa-developed codes (DRAW for durability analysis, DSO for sensitivity analysis, and RBDO for reliability-based design optimization) on Army vehicles such as the HMT Draw bar (40% weight reduction) and the Stryker A-arm (19.6% weight reduction) led to initial deliberation of these codes to port on TARDEC's HPC system for rapid assessment and recommendations for improving HMMWV system-level reliability. A total of $5 million in R&D funding from TARDEC, NSF, and industry has been invested in these three codes over a number of years. These three codes will follow the successful history of technology transfer of DADS. Successful scalability testing was carried out to learn how to achieve computational speed-up using HPC.

In 2008, TARDEC, Iowa, and other teams will launch RBDO for durability of the FMTV model to validate and further enhance the DRAW-DSO-RBDO/PBDO/MVDO software system on TARDEC's upgraded HPC with the new operating system Linux. In doing so, a large number of copies of the Iowa-developed software system will be installed on TARDEC's new HPC. Soon after this new study on the FMTV model, the Iowa team will be ready to train TARDEC engineers to use it for daily applications to various Army ground vehicle programs

Component- and System-Level RBDO of Nonlinear Systems with Correlated Input Variables

KK Choi, University of Iowa

In many RBDO problems, input random variables such as the material properties, fatigue coefficients and exponents, etc., are correlated. For the RBDO problem with the correlated input variables, a joint CDF of the input variables should be obtained. However, in practical applications such as Army ground vehicles, only the marginal CDFs and limited paired sampled data can be obtained using experimental testing. In this presentation, a copula is proposed to construct the joint CDF using the marginal CDFs. To obtain correct joint CDF, it is necessary to identify the correct copula using the marginal PDFs and paired samples. For this, a Bayesian method is used to investigate the minimum number of samples that is necessary for identification of the correct copula type. Once the joint CDF is obtained, Rosenblatt transformation is utilized to transform the original random variables into the independent standard normal variables for the inverse reliability analysis. When the input variables have a non-normal distribution, the Rosenblatt transformation becomes highly nonlinear, which in turn makes the performance function become highly nonlinear in terms of the independent standard normal variables.

It is well known that the second order Reliability Method (SORM) is necessary for accuracy of nonlinear and multi-dimensional performance functions. However, SORM requires the second-order sensitivities. In this presentation, the most probable point (MPP)-based dimension reduction method (DRM) is proposed for the inverse reliability analysis for accurate probability of failure calculation without requiring the second order sensitivities. Since the FORM-based reliability index is inaccurate for the MPP search of the nonlinear performance function, a three-step computational procedure is proposed to improve accuracy of the inverse reliability analysis:

probability of failure calculation using constraint shift, reliability index update, and MPP update. Using the three steps, a new DRM-based MPP is obtained, which estimates the probability of failure of the performance function more accurately than FORM and more efficiently than SORM.

Estimations of not only the component probability of failure but also the system probability of failure have been the main concern in structural reliability analysis for over three decades. In this presentation, the reliability analysis of the series system is considered since it is the most frequently encountered in practical engineering applications. The proposed MPP-based DRM is integrated with the Ditlevsen's second order upper bound by considering the joint probability of failure for the system reliability analysis and RBDO.

April 2nd, Wednesday (10:30-12:00am)
University of Michigan, Lurie Engineering Center, Level 4, GM Room

Presenting:
Thrust Area 5 – Vehicle System Integration, Optimization, and Robustness

Design for Lifecycle Cost using Time-Dependent Reliability Analysis
Zissimos P. Mourelatos, Amandeep Singh and Jing Li, Oakland University

Physics-based Shape Morphing and Packing for Layout Design
Georges Fadel, Clemson University

(no abstracts available)

April 23rd, Wednesday (9:30-11:00am)
University of Michigan, Lurie Engineering Center, Level 4, GM Room

Presenting:
Thrust Area 2 – Human Centered Modeling and Simulation

Three-Dimensional Joint Kinematics of the Upper Extremity in Reach Movements under Whole-Body Vibration Exposure
Heon-Jeong Kim, Bernard Martin University of Michigan

Convoy Driving with Secondary Tasks: Results of a Driving Simulation Experiment
Helen Fuller, Omer Tsimhoni University of Michigan