UNC CHARLOTTE

The WILLIAM STATES LEE COLLEGE of ENGINEERING

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12:30 pm to 3:00 pm, Friday, December 1, 2017 (1249 EPIC)

Abstracts

Shamir Bin-Karim

Optimal Control of a Relocatable Autonomous Underwater Vehicle for Gulf Stream Marine Hydrokinetic Energy Extraction

The Gulf Stream carries more than 4 kW per square meter of kinetic energy within less than 200 km of Cape Hatteras. However, while the Gulf Stream possesses consistent strength, its location can shift by 30 km or more over time, rendering fixed turbines impractical. As an alternative to fixed turbines, this work presents the concept and corresponding controller for an autonomous underwater vehicle (AUV), co-developed by NC State, UNC Charlotte, and the UNC Coastal Studies Institute, which generates energy while anchored and periodically relocates itself to remain in the strongest area of the Gulf Stream. To maintain an estimate of the Gulf Stream flow profile, a Kalman filter-based estimator blends a measurement of the flow speed at the AUV's location with intermittent secondary flow speed data (available through onshore radar and altimeter satellites). Model predictive control (MPC)-based spatiotemporal optimization is then used to optimize the location of the AUV along a cross-stream transect. The proposed real-time MPC strategy balances the need for instantaneous power maximization based on available information (termed "exploitation") and the need to maintain an accurate map of ocean current speed versus location (termed "exploration"). The control strategy has been validated through data from a numerical model of coastal circulation dynamics.

Dhanooj Bobba

Combined DEM-FEM Modelling of Shot Peening Process

Fatigue life of components is often improved by inducing compressive residual stresses on the component surfaces through the shot peening process in which the surfaces are impinged with many high speed spherical particles. The effectiveness of peening process is mainly controlled by two factors, namely coverage area and intensity, which in turn depend on several process parameters such as shot size, velocity, angle of impact etc. The intensity of the shot peening process is measured using a technique known as Almen intensity test. In this study, an Almen intensity test was modelled using the combination of DEM and FEM in Abaqus. Roughly 32,000 shots were modelled using discrete elements and the specimen was modelled using finite elements. A parametric study is performed, to study the effects of various process parameters on the intensity of the shot peening process. The results from this study are discussed in this presentation.

John Borek
(Christian Earnhardt and Benjamin Groelke)

A Comparative Assessment of Economic Model Predictive Control Strategies for Fuel Economy Optimization of Heavy-Duty Trucks

This presentation describes a family of novel optimal control approaches that fuse global, offline optimizations with a local, online corrections, in an effort to minimize fuel consumption for a heavy-duty truck. The online optimizations use economic model predictive control (MPC) to make refinements to a coarsely optimized target velocity profile from an offline dynamic programming optimization. Because the optimizations focus on the maximizing a profitability metric (fuel economy in this case) rather than simply tracking a setpoint, the underlying controllers are termed economic optimal controllers. Three candidate economic MPC formulations will be described: a time-based formulation that directly penalizes fuel consumption, a simplified time-based formulation that penalizes braking effort, and a distance-based convex formulation that maintains a tradeoff between energy expenditure and mobility. The performance of each approach will be presented for three representative route profiles, using a medium-fidelity longitudinal dynamics model for a heavy-duty truck, furnished by Volvo. Results demonstrate 4-7% fuel economy improvement across all three formulations, as compared with a baseline constant speed strategy. In addition to these results, we will present a detailed analysis of energy usage by "type" (aerodynamic losses, braking losses, and brake-specific fuel consumption) under each candidate control approach.

Ismael Boureima

Study of the Turbulent Mixing Layer in Highly Converged Condition

We present results from numerical simulations of the turbulent mixing layer between two fluids driven by a spherical implosion. The studied problem as defined by Youngs and Williams [1] is an abstraction of the Inertial Confinement Fusion (ICF) process. It involves a time-dependent pressure drive that sustains the implosion of an inner fluid (fuel) confined inside a shell in a slow-fast configuration. These successive accelerations amplify the imperfections at the fluid interface, known as Rayleigh-Taylor (RT) and Richtymer-Meshkov (RM) instabilities. At late times, the instabilities grow nonlinearly, then interact and mix, and subsequently turn the interface into a fully mixed and turbulent layer. The simulations were performed with the FLASH [2] code at a mesh resolution of 3072x1024x1024 corresponding to the radial, azimuthal and polar directions, respectively.

[1] Youngs, D. L., and Williams R. J., Intl. J Num. Meth. Fluids, 56 (8), 1597 (2008).
[2] Fryxell, B. et al., Astrophys. J. Suppl., 131 (1), 273 (2000).

Mitchell Cobb

Economic Iterative Learning Control with Application to Airborne Wind Energy Systems

Numerous advanced manufacturing, biomedical, and energy applications involve repetitive control. In these applications, *iteration-to-iteration* feedback can be used to improve performance from one iteration to the next without incurring transient errors that are inherent in time-domain feedback. Such control techniques, termed *iterative learning control*, have traditionally focused on improving setpoint tracking, without consideration of other objectives such as energy expenditure/generation, manufacturing time, or monetary cost. The work presented herein breaks that paradigm. Specifically, this presentation will detail a process by which iteration-to-iteration feedback is used to maximize a profitability metric rather than focusing merely on tracking of a pre-defined setpoint. The methodology has been applied to an airborne wind energy (AWE) system, where flying a wing with on-board rotors in repeated figure-8 patterns can produce substantially more energy than can be produced through stationary operation. Economic iterative learning control has been used to adjust the waypoints that define a figure-8 path at each iteration, in order to maximize the average power output of the system. The presentation will demonstrate, through simulation on a medium-fidelity 3D simulation model, how this control strategy achieves convergence to near-optimal figure-8 paths for a variety of initial conditions.

Ryan W. Copenhaver

Periodic Sampling in Modulated Tool Path Turning to Determine Cutting Stability

Unlike milling where the cutting edge constantly enters and exits the workpiece, the cutting edge engages the workpiece and stays in the cut until the cutting operation is completed in traditional turning operations. This produces undesirable long continuous chips, which decreases operator safety and reduces workpiece surface finishes. A solution is to use a custom tool path called Modulated Tool Path (MTP). MTP creates discontinuous segmented chips by superimposing a sine wave on the tool motion in the feed direction. Since the cutting edge is entering and exiting the cut, the system response resembles a forced vibration.

When determining the stability of a cutting process, a periodic sampling method can be applied to the in-process cutting responses of the tool (position, velocity, and acceleration signals). If a stable cutting response signal is sampled at the forcing frequency, the sampled points repeat. If an unstable cut is sampled at the forcing frequency, the sampled points vary due to the influence from the chatter frequency. Experiential results showing the application of the periodic sampling strategy for both stable and unstable cuts are provided.

Joe Deese
(Nihar Deodhar)

Nested Plant/Controller Co-design of a Complex System: Application to Airborne Wind Energy System

In many active systems, the optimal control design depends on the plant, and vice versa. In response to this, a large number of publications have addressed the combined optimization of the plant and controller, termed co-design, in the presence of well-defined, simple numerical models. However, these legacy techniques suffer two key drawbacks: (i) the underlying optimization tools are local in nature and only achieve global optimality in the presence of convexity, and (ii) the techniques are not easily extended to the experimental realm, where it is possible to adapt control parameters during experiments to accelerate the design process. This presentation will describe a nested co-design strategy where optimal design of experiments techniques are used to generate a set of plant designs at each iteration, over a prescribed design space, whereas continuous-time adaptation is used to optimize control parameters over the course of simulations/experiments. At the end of each iteration, the design space is shrunken based on a response surface characterization and hypothesis testing. This presentation will demonstrate the efficacy of the nested co-design process for an airborne wind energy (AWE) system, in which the center of mass, stabilizer surface area, and trim pitch angle are optimized for flight performance.

Mohan Surya Raja Elapolu

Kapitza Conductance of Symmetric Tilt Grain Boundaries of Monolayer Boron Nitride

Reverse nonequilibrium molecular dynamics (RNEMD) simulations are used to understand thermal behavior of two-dimensional hexagonal boron nitride (h-BN) nanoribbons containing symmetric tilt grain boundaries. The impact of misorientation angle, grain length and temperature on the Kaptiza conductivity of grain boundaries and effective thermal conductivity of nanoribbons are studied. In the RNEMD method a constant heat flux is induced in the system which generates a temperature profile along the longitudinal direction of the ribbon. Effective thermal conductivity of ribbons and Kapitza conductance of grain boundaries are calculated based on the steady-state temperature profiles. Our results showed a jump in the steady-state temperature profiles at the location of grain boundaries. Kapitza conductance of the grain boundaries is calculated using these temperature jumps. Analysis of the data showed that the temperature jumps at the grain boundaries are due to phonon scattering at the grain boundaries. Phonon scattering is due to the mismatch of phonon spectrum of grain and grain boundary atoms. An increase in misorientation angle increases the defect density at the grain boundary resulting in increase of phonon scattering which decreases the Kapitza conductivity of the grain boundary. The decrease in Kapitza conductivity decreases the effective thermal conductivity of the nanoribbon. An increase in grain length increases the Kapitza conductance of grain boundaries and effective thermal conductivity of the ribbons. Temperature has no significant effect on Kapitza conductance, but effective thermal conductivity decreases with an increase in temperature.

Chunjie Fan

Rotating Measurement of Crystalline Silicon during Nano-indentation

This research desires to measure the rotation of air bearing during nano-indentation by using piezoelectric actuator, encoders and capacitive sensors. This silicon indentation system includes a piezoelectric actuation flexure and a rotation air bearing supporting system. The piezoelectric actuated flexure with two stages will supply the displacement for penetrating the silicon. The displacement of each stage will be measured by using the cap gages. The air-bearing supported system will show the rotation which is driven by phase changing of silicon and pressure between the sharpened diamond tip and the crystalline silicon during indenting. The rotation angles and penetration depth will be measured with the radial encoder and two capacitance gauges, respectively. The operation environment is under constant temperature. The idea of rotation measurement is introduced. The sequence of experiment is stated, together with measuring methods.

Andrew Honeycutt

Surface Roughness of Period-2 Milling Bifurcations

CNC milling operations are important for discrete part manufacturing. CNC machines offer excellent accuracy and high automation which provide cost effective solutions for making discrete parts. Surface finish of a machined part is also a metric that needs to be considered for a part’s performance. Traditionally, the dynamic behavior of a milling operation is either classified as stable or unstable (also known as chatter). Several methods exist to evaluate the stability of a milling operation, but one unique method is known as once-per-tooth sampling. Once-per-tooth sampling is a periodic sampling technique that samples the vibrational state of the cutter with the passage of each cutter tooth. This effectively samples the response (cutter vibration) of a dynamic system at the forcing frequency (spindle speed). A stable milling operation under synchronous forced vibration has a dynamic response with a time period equal to the forcing period. A special type of unstable behavior known as a period-n bifurcation has a response period that is an integer multiple, n, of the forcing period. Surface roughness while machining under period-2 conditions is compared to stable machining surface roughness. Stable conditions lead to better surface finish, but both surface finish results are predictable using numerical simulation.

Shank S. Kulkarni

New Constitutive Model for Polyurea

Polyurea is a special type of elastomer with high damping capacity. It shows highly non-linear viscoelastic characteristics which are not accurately modeled yet. The purpose of this study is to model the behavior of polyurea at low, intermediate and high strain rates. A new constitutive model for polyurea is presented using a superposition of hyperelastic and a viscoelastic model. The four term Ogden model is used to represent rate independent hyperelastic response. Quasi-static experimental data is used to fit the hyperelastic model. The standard linear solid (SLS) model is also used to represents the rate dependent viscoelastic response for high strain rates. All model parameters are found by curve fitting the response of polyurea under uniaxial tension and compression tests. A separate set of parameters is found for tension and compression behavior. The proposed model is efficient for simulating behavior of polyurea over very wide range of strain rates (-294 to 9000/s).

Yue Peng

Improved Gear Inspection Based on a Three-dimensional Model

Tactile measurement and line-oriented evaluation have been the dominant methods for gear flank inspection. The procedure in current gear standards is based on measuring one profile and one helix per tooth on selected gear teeth (usually four teeth selected), and evaluating the lines for deviation parameters. However, for modern gears, these parameters are constrained by the limited number of lines and teeth inspected to represent complex features and common information in all teeth. In this research, area-oriented gear inspection methods are under investigation to represent and evaluate the features across the flank surfaces with proper parameters and to calculate the deviations with three-dimensional measured points covering the surfaces. Firstly, the reference geometry is extended from involute curves to involute surfaces. Secondly, the deviations are defined in a three-dimensional space and represented as surface. Thirdly, the deviation map is characterized by the decomposition method with Chebyshev polynomials to evaluate the areal gear deviation parameters. A modification artefact with certified evaluation parameters is measured and evaluated with area-oriented methods. The discrepancies between the results are less than 2 µm, which is within the 3 µm measurement uncertainty of certificate.