PRESENTATIONS

Seamless Interfaces for Building High Performance Textiles and Wound Dressing

CDT Taler Brazell, CDT Riley Ping Medvigy, CDT Virginia Phillips, and
COL Michael D Phillips, USMA and Andrew Capulli and Kevin Kit Parker, Harvard

With small diameters and pore sizes, a large surface area to volume ratio, and tunable properties, nanofibers are an ideal scaffold material for tissue engineering and textile manufacturing. When spun from different polymers, nanofibers can exhibit a range of elasticities and scaffold mechanics necessary to mimic the mechanical properties of the skin. Using a perforated reservoir that uses centrifugal forces to extrude fibers, automated Rotary Jet Spinning (aRJS) has been demonstrated as a rapid and efficient method to produce nanofibers of varying mechanical strength with controlled fiber deposition. Currently, stiff bandages and clothing manufacturing lack a biomimetic range of motion. Although sewing different materials together has been utilized to mimic skin biomechanics in clothing, the seams in multi-material clothing are restrictive and likely points of failure. There is a need for a seamless multi-material solution that can more accurately recapitulate the dynamic properties of the skin. We hypothesize aRJS can be used to create a multi-material sleeve that enables and enhances a full range of motion for the end user in wound dressings and high performance applications. To test this hypothesis, we performed a biomechanical analysis of arm movement to motivate the design of our zoned scaffold. During flexural movement, we show that sections of the human arm experience heterogeneous extension and compression from the forearm to the shoulder. Based on these results, we zoned a soft polyurethane and stiff nylon onto a single cylindrical mandrel to create a seamless textile and tested its mechanical properties biaxially. Using 3D printing technology, we manufactured a scaled model of a human arm mandrel to test our ability to zone different materials at specific sections on the arm. Our results show that aRJS spun seamless materials have integrity at their interface as the structure remained intact when strained along the stitch-free material interface. aRJS can be used to create a multi-material, seamless sleeve to allow for therapeutic compression on the forearm and full range of motion at the elbow and upper arm. Without the need of additional sewing or stitching, zoning materials in this method provides a path to increasing the efficiency of textile manufacturing.

KEYWORDS: Nanofibers, Automated Rotary Jet Spinning (aRJS), Scaffold, Seamless, Zoning

CONTACT: CDT Taler Brazell, USMA, West Point, NY 10996
Email: Taler.Brazell@usma.edu TEL: 702-985-5791

A Graph Theoretic Model of Information Diffusion

Dr. Lisa Lowrance, USMA and Dr. Norbou Buchler, ARL

Consider the problem of information passing in a network. When one person is given a piece of information in a network and every person is allowed to pass this piece of information to exactly one person at any discrete time step, we give an optimal algorithm to pass this information to every person in the network in the fewest number of time steps. We first give an algorithm for any tree. This will then be generalized to all simple graphs by applying the algorithm over all spanning trees. A similar algorithm extends to the case when more than one individual is initially given the piece of information. These processes are then applied to specific classes of graphs.

KEYWORDS: Social network, Communication network, Information diffusion, Graph, Algorithm

CONTACT: Dr. Lisa Lowrance, D/MATH, USMA, West Point, NY 10996
Email: Lisa.Lowrance@usma.edu TEL: 845-938-4014

Generalizing Zeckendorf's Theorem: The Kentucky Sequence

Minerva Catral, Pari Ford, Pamela E. Harris*, Steven J. Miller, and Dawn Nelson

Zeckendorf's theorem states that every positive integer can be uniquely decomposed as a sum of non-consecutive Fibonacci numbers. We generalize the Zeckendorf condition to generate (s; b)-Generacci sequences which give unique decompositions of positive integers as a sum of (s; b)-Generacci numbers. In fact the (1; 1)-Generacci sequence is the Fibonacci sequence. In this talk we focus on the (1; 2)-Generacci sequence, which we call the Kentucky sequence. Previous methods to determine the behavior of the number of summands for integers in a given interval do not apply to such a sequence (whose recurrence relation has zero leading coefficient) yet we can prove that this sequence displays Gaussian behavior. As a consequence of our proof we rederive many properties of the Fibonacci polynomials. Furthermore, we show that the distribution of gaps between summands in the (1; 2)-Generacci decomposition converges to exponential decay.

KEYWORDS: Fibonacci numbers, Generacci sequence

CONTACT: Pamela E. Harris, D/MATH, USMA, West Point, NY 10996
E-Mail: Pamela.E.Harris@usma.edu TEL: 845-938-6729

Robust Particle Filters for Diagnosis of Airframe Structures

Mulugeta A. Haile, ARL

Crack growth in airframe structure may be considered as a nonlinear dynamic process where the crack size at each time step is predicted by a physical damage model such as the Paris-Erdogan equation. The latter, even supplemented with crack-tip plastic zone correction factor, rarely provides accurate prediction of crack-size. In airframe monitoring, damage is diagnosed using sensors that are streaming noisy data that is so often unreliable. Taken separately, crack-size prediction using either physical damage model or sensors may result in a highly erroneous estimation that may increase the risk of operation and the cost of maintenance. The goal of this paper is to develop a data-informed diagnostic framework that combines the predictions of a physical damage model and evidence from ultrasonic sensor data to provide accurate estimation of crack-size in rotorcraft structures. The data-informed approach obtains the most probable crack-size using a sequential Monte Carlo method known as Particle Filters. To validate the approach, three Al7075-T6 nested-angle plates were tested using rotorcraft spectrum loads. Results show that the prediction error of the data-informed method, as measured by root mean square deviation from the true value, is less than half of the error of both the Paris-Erdogan and NASGRO models.

KEYWORDS: Airframe structures, crack growth, plastic zone

CONTACT: Mulugeta A. Haile, ARL, APG, MD 21005
Email: mulugeta.a.haile.civ@mail.mil TEL: 410-278-5289

Retrieving 3D Facial Features from LWIR Polarimetric Images

Dr. Alex J. Yuffa, Dr. Kristan P. Gurton, and Dr. Gorden Videen, ARL

We use a polarimetric camera to record the Stokes parameters and the degree-of-linear polarization of long-wavelength infrared (LWIR) radiation emitted by human faces. These Stokes images are combined with Fresnel relations to extract a surface normal. The surface normal is integrated to yield a three-dimensional facial image. One major difficulty of this technique is that the normal vectors determined from the polarizations are not unique. We overcome this problem by introducing an additional boundary condition on the subject. The major sources of error in producing inversions is noise in the images caused by scattering of the background signal and the ambiguity in determining the surface normals from the Fresnel coefficients.

KEYWORDS: Facial recognition, polarimetric, LWIR, thermal image, polarimetry, Stokes parameters

CONTACT: Dr. Alex J. Yuffa, ARL, Adelphi, MD 20783
Email: alexey.j.yuffa.ctr@mail.mil TEL: 720-933-0654

Automated Demand Response of Thermal Load with a Photovoltaic Source for Military Microgrids

CDT Dylan Smith and Dr. Aaron St. Leger, USMA

Energy consumption by United States Army troops operating in deployed environments has become an important issue. The cost of providing diesel fuel for generators to these environments bears a heavy risk and fiscal cost due to intensive precautions needed to defend fuel convoys from enemy attack. Photovoltaics have shown to be effective at reducing diesel fuel requirements, but introduce additional variability in demand due to their intermittent nature. Batteries can mitigate this, but have shown to be cost ineffective in deployed military applications. A structurally insulated panel (SIP) housing prototype, or SIP-Hut, for forward operating bases has been developed with the potential to reduce thermal load by a factor of ten in comparison to traditional housing structures. This work leverages the thermal envelope of the structure to create elasticity in heating/cooling demand. More specifically, this paper investigates coupling automated demand response of the SIP-Hut Environmental Control Unit (ECU), which is the primary load in these structures, with a photovoltaic source. The objectives are to minimize the frequency of generator operation and mitigate variability of the intermittent PV source to reduce diesel fuel consumption. A detailed thermal model of the SIP-Hut is presented and validated based on data obtained from a prototype SIP-Hut. An ECU demand response controller, developed using model based design, is presented with simulation results.

KEYWORDS: Smart-Grid, Power, Energy, Solar

CONTACT: CPT Jeremy Spruce, MSE, USMA, West Point, NY 10996
Email: Jeremy.Spruce@usma.edu TEL: 845-938-5607

Toward a Rigorous Justification of the Three-Body Impact Parameter Approximation

Adam S. Bowman, USMA

The three-body impact parameter approximation is a "semiclassical" model in quantum scattering theory wherein two large masses interact with one small mass. We study this model in one spatial dimension. We demonstrate that the model's predictive power for a particular scattering channel becomes arbitrarily good as the masses of the two heavy particles are made larger. Our approach studies the S-matrix for this channel. We show that the wave functions associated with the impact parameter model can be made arbitrarily close to the full three-body wave function, uniformly in time, provided one of the large masses is fixed in place. We also show that such a result probably will not hold if we allow all the masses to move.

KEYWORDS: Quantum scattering theory, functional analysis, partial differential equations, semiclassical physics

CONTACT: Dr. Adam S. Bowman, USMA, West Point, NY 10996
Email: adam.bowman@usma.edu TEL: 845-938-2453

CFD Aerodynamic Characterization of a High Maneuverability Airframe

CDT Craig J. Coyle, USMA and Dr. Sidra I. Silton, ARL

A computational fluid dynamics (CFD) approach to the aerodynamic characterization of a new design for a guided shoulder or artillery fired projectile is presented. The commercial CFD software *CFD++* version 14.1.1 was utilized to apply the Reynolds-Averaged Navier-Stokes equations with the *k*-□-*Rt* turbulence closure model to the airframe. Several canard deflection angles for roll control over multiple angles of attack were investigated. The force and moment coefficients of the projectile as a whole, as well as several of the individual projectile components were determined and plotted as functions of angle of attack and canard deflection angle. Additionally, flow visualizations were created using the analysis software *EnSight* to investigate the flow interactions between the airfoil shaped canards and the flat plate fins located at the base of the projectile. Tip and root vortices produced by the canards and interacting provided a significant area of interest and focus for future work.

KEYWORDS: Computational Fluid Dynamics (CFD), *CFD++*, RANS, Projectile Aerodynamic, Vortex Interactions, High Maneuverability Airframe

CONTACT: CDT Craig J. Coyle, USCC, USMA, West Point, NY 10996
Email: Craig.Coyle@usma.edu TEL: 845-304-2104

Applied Robotics for Installation and Base Operations – Industrial Hygiene (ARIBO-IH)

LTC Christopher Korpela and MAJ Dom Larkin, USMA

US forces that operate around unknown chemical and biological hazards must wait for specialized units to confirm the presence of hazardous agents. The purpose of the Applied Robotics for Installation and Base Operations – Industrial Hygiene (ARIBO-IH) project is to demonstrate the potential capabilities of an unmanned robot to the future of industrial hygiene. Chemical detection robots at the company-level could greatly enhance the effectiveness of ground forces. ARIBO-IH could eliminate unnecessary human exposure to potentially dangerous chemical, biological, radiological and nuclear (CBRN) environments by attaching gas, temperature, and humidity sensors to a tele-operated robot chassis in order to remotely report environment statistics. The first year of this multi-year project produced a proof of concept platform.

KEYWORDS: Unmanned Systems, Chemical Detection, Autonomous Recharging

CONTACT: LTC Christopher Korpela, EECS, USMA, West Point, NY 10996
Email: christopher.korpela@usma.edu TEL: 845-938-5574

Planar Laser Induced Fluorescence in Spray Analysis

CDT Zachary Lee, CDT Tyler Sowell, CDT John Beck, and CDT Zachary Glass, USMA

Accurate investigations into sprays are significant because of the many applications of sprays including fuel injection. However, conventional optical methods are limited within dense, near-nozzle regions. As such, other methods such as X-ray computed tomography (CT) have been employed. Experiments at Stanford University have yielded results showing the mass distribution of sprays from custom-made pressure-swirl atomizers, but further experimentation is necessary to confirm the accuracy of these results. Planar laser induced fluorescence (PLIF) experiments have been conducted at the Army Research Lab in Aberdeen, MD to analyze liquid sprays with 150 parts per billion of Rhodamine WT dye through the same nozzles. Images were captured by a high-speed camera with a filtered lens. Measurements are taken from directly below the atomizer exit plane to approximately thirty nozzle diameters downstream. The intensity of the fluorescence correlates linearly with the amount of Rhodamine WT, thereby allowing for the calculation of the mass distribution of the liquid spray. Because both laser induced fluorescence and X-Ray CT scanning provides a mass distribution measurement, these results can be directly compared.

KEYWORDS: Spray, Fuel Injection, Laser Induced Fluorescence, X-Ray Computed Tomography

CONTACT: CDT Zachary T. Lee, USCC, USMA, West Point, NY 10996
Email: zachary.lee@usma.edu TEL: 757-645-8758

Quantifying User Improvement in Pattern Recognition-Based Myoelectric Prosthesis Control

MAJ Michael A. Powell, USMA and Dr. Nitish Thakor, Johns Hopkins University

We assessed the ability of four transradial amputees to control a virtual prosthesis capable of nine classes of movement both before and after a two-week training period. Subjects attended eight one-on-one training sessions that focused on improving the consistency and distinguishability of their phantom hand and wrist movements using visual biofeedback from a virtual prosthesis. The virtual environment facilitated the precise quantification of three prosthesis control measures. During a final evaluation, the subject population saw an average increase in movement completion percentage from 70.8% to 99.0%, an average improvement in normalized movement completion time from 1.47 to 1.13, and an average increase in movement classifier accuracy from 77.5% to 94.4% ($p<0.001$). Additionally, all four subjects were reevaluated after eight elapsed hours without retraining the classifier, and all subjects demonstrated minimal decreases in performance. Our analysis of the underlying sources of improvement for each subject examined the sizes and separation of high-dimensional data clusters and revealed that each subject formed a unique and effective strategy for improving the consistency and/or distinguishability of his or her phantom limb movements. This is the first longitudinal study designed to examine the effects of user training in the implementation of pattern recognition-based myoelectric prostheses.

KEYWORDS: Pattern Recognition, Myoelectric, Electromyography, Rehabilitation

CONTACT: MAJ Mike Powell, USMA, West Point, New York 10996
Email: michael.powell@usma.edu TEL: 845-938-6419

Regular Tilings and generalized Zeckendorf decompositions

CDT David J. Townliand and Dr. Pamela E. Harris, USMA

Zeckendorf's theorem states that every positive integer can be uniquely decomposed as a sum of non-consecutive Fibonacci numbers. In this talk, we look at creating sequences using regular tilings of the plane to generalize Zeckendorf decompositions. We will focus on our preliminary results using the regular triangular tiling of the Euclidean plane.

KEYWORDS: Zeckendorf Decompositions, Fibonacci Numbers, Regular Tiling of the Plane

CONTACT: CDT David J. Townliand , USMA, West Point, NY 10997
Email: David.Townliand@usma.edu TEL: 509-881-5338

A New Kind of Cyber Education

Mr. John Cole, ARL

As Dr. Pellegrino has noted, "our knowledge of the cyber world changes so quickly that the line between fundamental science and research and its application is razor thin". This timeline requires the tight integration of Research, Operations, Partnerships, and Education (ROPE).

In this environment Cyber Education must be pursued through very close collaboration of educators, researchers, and students with all participants acting as co-developers of new technologies, methods, and practice that do not exist today. Researchers must spend part of their time as educators, and as educators learn from their students as they together develop future for Army cyber operations.

Cyber Education must no longer be a standalone activity frozen in time teaching only network analysis and 'crypto' (cryptography and cryptanalysis). It must match the rate of change in technology with highly dynamic content; it must meet the soldier need to transition to cyber operations as they develop; it must provide the researcher with feedback from the practitioner about technologies; and it must be used to educate researchers in areas of military practice and methods, such as concepts of maneuver.

With a much different Cyber Education offering, the Army can build the cyber work force it needs for current and projected needs.

KEYWORDS: CEMA, cyber, operations, education

CONTACT: John L. Cole, ARL, RDRL-CIN-D, APG, MD
Email: jack.cole@us.army.mil Tel: (410) 278-9276

Theoretical Characterization of Visual Signatures (Muzzle Flash)

CDT Gavin M. Chase, CDT Oliver E. Di Nallo, and Dr. David O. Kashinski, USMA and
Dr. Edward Byrd, ARL

We are investigating the accuracy of theoretical models used to predict the visible, ultraviolet and infrared spectra of product materials ejected from the muzzle of currently fielded systems. Recent advances in solid propellants have made the management of muzzle signature (flash) a principle issue in weapons development across the calibers. *A priori* prediction of the electromagnetic spectra of formulations will allow researchers to tailor blends that yield desired signatures and determine spectrographic detection ranges. We are currently employing quantum chemistry methods at various levels of sophistication to optimize molecular geometries, compute vibrational frequencies, and determine the optical spectra of specific gas-phase molecules and radicals of interest. Electronic excitations are being computed using Time Dependent Density Functional Theory (TD-DFT), while the optimized geometries and vibrational frequencies are being computed using Density Functional Theory (DFT), Møller-Plessent Second Order Perturbation Theory (MP2), and Hartree-Fock Self Consistent Field (HF-SCF). A comparison of computational results to experimental values found in the literature is used to assess the affect of basis set and functional choice on calculation accuracy. The current status of this work will be presented at the conference.

KEYWORDS: Time Dependent Density Functional Theory, electromagnetic spectra, muzzle flash

CONTACT: CDT Gavin M. Chase, USMA, West Point, NY 10996
Email: Gavin.Chase@usma.edu TEL: 845-596-5828

Weather-Influenza Relationship across the Southwest United States

Dr. Adam J. Kalkstein, USMA

Predicting cases of influenza in advance remains a challenging problem for scientists across numerous disciplines. While there is increasing evidence that cool, dry air acts to exacerbate the spread of the disease in laboratory settings, few studies have examined such weather-influenza relationships among the human population. Here, winter season hospital admissions are examined for four cities in the Southwest United States to determine if specific climatic conditions are associated with elevated numbers of influenza-related hospital admissions. The results suggest that passages of cool, dry air masses are often followed by increases in hospital admissions, although the relationships vary somewhat by city. A closer examination of specific meteorological variables reveals there is the potential to create a predictive model which can possibly be used to forecast influenza-related hospital admissions in advance.

KEYWORDS: Influenza, Health, Weather, Climate, Air Mass

CONTACT: Dr. Adam J. Kalkstein, D/GEnE, USMA, West Point, NY 10996
Email: Adam.Kalkstein@usma.edu TEL: 845-938-3403

Information Theoretic Security: Secrecy, Authentication and Integrity

Dr. Eric Graves, ARL

Secrecy, authentication and integrity are three primary concerns in secure communications. Secrecy is needed in order to hide valuable information from an eavesdropper, while authentication is needed to ensure that this eavesdropper can't pretend to be a valid participant, and integrity is required to ensure that no information may be modified when in rout towards the intended destination. Each concern is a potential network vulnerability and a open research topic for communication engineers. In both simple and more complex communication networks information theoretic practices can be used to guarantee each of these concerns. Information theoretic results are of importance because they represent some of the strictest requirements for security; Information theoretically secure secret information will never be learned by unintended parties, while authentication and integrity will guarantee that any deception or manipulation will be detected with exponential probability. Furthermore, these practices not only address these concerns but also simultaneously optimize the rate of transmission of information. This work develops a common methodology which address all three areas of concern and discusses practical implementations of these methods.

KEYWORDS: Information Theory; Information Theoretic Security; Authentication; Integrity; Secrecy; Key Sharing

CONTACT: Eric Graves, ARL, Adelphi,MD 20783
Email: ericsgraves@gmail.com TEL: 352-215-4555

Mitigating the Impact of Storm Surges through Smart Coastal Development

CDT Nathaniel A. Marks and CDT Alexis G. Martinez, USMA

Storm surges continue to plague coastal areas across the eastern United States, and as sea levels continue to rise, damaging storm surges will likely become more frequent and more severe. The goal of this research is to compare surge damage across various coastal regions to determine the role of storm surge and coastal development in mitigating storm damage. Data from the National Oceanic and Atmospheric Administration (NOAA) were used to examine storm surge heights in east coast locales, and damage estimates were provided by the Federal Emergency Management Agency (FEMA). This research seeks to identify a relationship between advanced coastal practices and the reduction in damage caused by storm surge, and will highlight the impact that sustainable, responsible coastal building practices have on reducing storm surge damage.

KEYWORDS: Hurricanes, Storm Surge, Coastal Development, Urbanization, East Coast

CONTACT: CDT Nathaniel A Marks, USMA, West Point, NY 10997
Email: nathaniel.marks@usma.edu TEL: 678-371-2150

Hierarchical Assembly of DNA Bio-Templated Nano-wire and Nano-tube Films for Lightweight Multi-functional Materials

LTC John F. Burpo, MAJ Stephen J. Winter, CDT Benjamin E. Barclay, CDT David M. Brown, CDT Shawn P. Cooper, CDT Connor H. Mulhere, and CDT Alex Parra, USMA

DNA hydrogels can serve as 3-dimensional bio-templates for tunable nano-porous materials that serve both as electrochemical power sources and structural material. We present a general approach to 1) form a DNA hydrogel; 2) sensitize the DNA bio-template using catalytic palladium ions to mediate the electroless deposition; 3) synthesize 3-dimensional networks of copper and nickel nano-wire films via electroless deposition; 4) synthesize inorganic salt templated square cross-section nano-tubes that can be integrated into a hierarchal nano-material assembly. Such multi-functional electro-mechanical materials are envisioned to decrease the systems mass across a broad range of Army platforms and serve as a nano-architecture for other applications such as photovoltaics, catalytic systems, sensors, and energy absorption.

KEYWORDS: DNA hydrogel, bio-templates, nano-materials, electrochemical, biotemplating

CONTACT: MAJ Stephen J. Winter, C&LS, USMA, West Point, NY 10996
Email: stephen.winter@usma.edu TEL: 845-938-4095

Computed Tomography (CT) Analysis for Ballistic Research Applications

Kathryn L. Loftis, Kevin M. Jubb, and Cameron H. Good, Churchville, MD and Autumn R. Kulaga, Natalie L. Eberius, and Patrick J. Gillich, ARL

The Warfighter Survivability Branch of the U.S. Army Research Laboratory has developed novel computed tomography (CT) methods to non-invasively examine results of ballistic and blast testing. Our group recently obtained a mobile, medical grade General Electric BrightSpeed Elite CT Scanner which is ideal for scanning biological tissue. However, it can be optimized for scanning higher density objects including body armor, soldier equipment, gelatin blocks, biological targets, fragmented munitions, and a variety of test devices, thus providing a method of non-destructively analyzing these items. With regards to ballistics research, different protocols and analysis methods have been developed to compare equipment deformations and quantify damage of body armor, perform pre- and post-examination of biological targets and test devices (e.g., thoracic rig), and locate and characterize fragments within body armor. Preliminary results from a subset of our experiments will be presented.

KEYWORDS: Ballistics, Computed Tomography, Retopology, Volume Rendering, Radiographic Analysis, Target

CONTACT: Patrick Gillich, ARL, WSB, APG, MD, 21005
Email: Patrick.j.gillich.civ@mail.mil TEL: 410-278-6332

Military Injury Research for Evaluating Human Vulnerability in Combat

Karin A. Rafaels, and Patrick J. Gillich, ARL and Kathryn L. Loftis and Nitin M. Moholkar, Churchville, MD

Improved protection could be realized with a better understanding of the biomechanics of injury. Design of less injurious environments depends partly on knowledge of the effects of specific kinds and amounts of energy on specific human tissues. Quantification of the injury-related responses of critical body areas to mechanical forces, especially from the complex military environment, is needed. First, one must replicate the injury mechanism in a repeatable and controllable manner to provide a consistent application of energy to fully understand the injury-related responses. Second, the injury mechanism must be applied to an appropriate injury model to obtain mechanical parameters for determining and defining limits of human tolerance to injury, including whole-body and regional tolerances, the effect of human and environmental variables on tolerance, long-term effects, and survival of extreme impact. From this, the probability of injury can be determined which can lead to improvements in injury assessment technology, including development of means for assessing the important debilitating injuries and causes of fatality, improvement of surrogates, and developments of computer models to predict injury in complex scenarios.

KEYWORDS: Biomechanics, injury, modeling

CONTACT: Karin A. Rafaels, PhD, ARL, APG, MD 21005
Email: karin.a.rafaels.civ@mail.mil TEL: 410-278-9459

Spray Characteristics of a Liquid Micro-Jet

Michael Tess, Luis Bravo, Matthew Kurman, and Chol-Bum Kweon, ARL and Mark Dorner and Jack Jerovsek, Baker Engineering, Inc.

The fueling method for a modern compression ignition engine involves the injection of liquid fuel at very high Reynolds number, in a single or multiple pulses, directly into the combustion chamber. Recent trends toward engine downsizing, motivated primarily by emissions and fuel efficiency regulations but also by improving power density, are constrained by the optimization of the spray characteristics to the engine geometry. At any given thermodynamic state of the in-cylinder charge, however, liquid impingement on the chamber walls must be avoided for proper combustion. Because liquid penetration length is linearly dependent on orifice diameter, one method to control impingement is to reduce the orifice diameter in proportion to the cylinder bore diameter. Accordingly, this research discusses the development of a high-pressure, common-rail type diesel injector capable of meeting the performance requirements of a small-bore diesel engine. The injector nozzle featured a single axial hole with an orifice diameter equal to approximately 50 μm. The effects of solenoid energizing time, fuel pressure, and power drive settings on the dynamic rate of injection were parametrically investigated. High-speed imaging techniques were implemented to visualize the evaporating spray and evaluate the global characteristics such as liquid and vapor penetration length. The experimental results were compared to high-fidelity CFD models using RANS and LES computations. Finally, the manufacturing technologies capable of drilling micron-sized holes through high-strength steel are assessed for their application in diesel injector systems.

KEYWORDS: Diesel engine, fuel injector, orifice diameter, spray

CONTACT: Michael Tess, VTD, ARL, APG, MD 21005
Email: michael.tess@us.army.mil TEL: 410-278-9719

Modeling Human Physiology as a System of Systems

MAJ Benjamin Thirey, USMA

Modern medicine has exploded with observations regarding how to best to optimize human performance and enhance health through interacting physiological interactions. Many of these observations stem from medical observations over time or results from double-blind studies which do not take into consideration the large number of interacting variables that exert influence on an outcome. We propose a model which strives to approach the overwhelming complexity of human physiology and model it as an interacting network of networks. Each sub-network influences the others and is composed of a similar set of functions such as absorption, excretion, communication, resource utilization, and proximity to other systems via physiological pathways. There is already a wide variety of work on cellular signaling and metabolic pathways, but much less has been done on work at the scale of a body. Such an approach allows research to investigate the effects of promising treatments in a cost effective manner prior to *in vivo* confirmation.

KEYWORDS: Network Science, Variable Interaction, Mathematical Physiology, Synthetic Biology

CONTACT: MAJ Benjamin Thirey, USMA, West Point, NY 10996
Email: benjamin.thirey@usma.edu TEL: 845-938-5931

Overview of Adaptive Training and USMA Project Ties

Dr. Keith Brawner, ARL

ARL's HRED division has adaptive training research components. Adaptive training is instruction where guidance and content change in real-time in response to the needs of the learner. Taxonomically, adaptive training includes research in adaptive tutoring, virtual humans, distributed learning, and training/learning effectiveness. Research objectives in this area include distribution of training content, multiple device content provisioning, customization of content for students/users, automation and augmentation of content creation through use of tools, selection among instructional strategies, team-based tutoring and feedback, and others. ARL's Learning in Intelligent Tutoring Technologies (LITE) Lab representative will speak on the current status of several research projects, current "research overflow" projects appropriate for cadets, examples of research projects scheduled for USMA in the Spring term, and samples of research projects performed jointly with USMA in the past.

KEYWORDS: Training, Adaptive Training, Instructional Management, Learner Modeling, Affect, Machine Learning, Optimization, classification and detection

CONTACT: Dr. Keith Brawner, ARL, HRED, STTC, Orlando, Florida
Email: Keith.W.Brawner.Civ@us.army.mil TEL: 407-380-4648

Statistical Analysis of UAV Target Location Error using Circular Error Probable and Alternative Methods

CDT Brad Brownfield and CDT Ian Williams, and MAJ Julie Layton, USMA

Evaluating how well a weapon fires has been calculated using a method called Circular Error Probable (CEP) since World War II by the Department of Defense. 50% CEP measures the distance from the target that 50% of the population of shots have landed. One downfall of this method is that it requires a bi-variate normal distribution, which is very unlikely. My work with Army Evaluation Center from May to July 2014 we assessed the ability of the TUAS Shadow UAV to track targets and alternative methods to calculate target location error when the distribution does not have a bi-variate normal distribution.

KEYWORDS: Bivariate Normal, TUAS Shadow, Alternatives to 50% CEP

CONTACT: MAJ Julie A. Layton, USMA, West Point, NY 10996
Email: julie.layton@usma.edu TEL: 845-938-6093

Toward a Full-Spectrum (Hybrid FEA/SEA) Shock-Response Analysis Methodology: *Motivation, Overview, and Update*

Prof. R. David Hampton, USMA

A full-spectrum, transient-capable, dynamical-analysis methodology is sometimes needed to handle problems for which deterministic methods alone are inadequate, due to such considerations as model size, frequency limitations, and computational overhead. For such problems a treatment is needed that marries the power and maturity of a deterministic method – such as Finite Element Analysis (FEA), suitable only for lower frequencies, to a stochastic method – such as Statistical Energy Analysis (SEA), which is quite well-suited for higher frequencies. A hybrid FEA/SEA approach has emerged over the last decade that is quite effective for many such problems. To date, however, both SEA and hybrid FEA/SEA are limited, in the literature, to steady-state analysis. Recently a theory for Transient Statistical Energy Analysis (TSEA) has been developed and applied incipiently, in unpublished work by Robin S. Langley of the Cambridge University Engineering Department (CUED, Cambridge, England), for the case of impulsive point-loading acting on a general built-up system. This TSEA theory is applicable to any system for which a Statistical Energy Analysis (SEA) model exists. The present work reviews the motivation for a hybrid TSEA methodology incorporating such a development, and presents a brief overview and update regarding the current state of the art.

KEYWORKS: Statistical Energy Analysis, Transient Statistical Energy Analysis, Full Spectrum Dynamics, Hybrid Analysis, Overview, Shock Response, Mechanical Shock, Blast Loading

CONTACT: Prof. R. David Hampton, D/CME, USMA, West Point, NY 10996
Email: Roy.Hampton@usma.edu TEL: 845-938-8398

The Real-Time Kinetics of Activating a Single Gene in a Model Cell

J. Kenneth Wickiser, Ph.D., CDT Jeremy McMurray, CDT Michael Tobin, and CDT Lisa Junta, USMA, Matthew Brown, Harvard and Keila Sheetz, Northeastern U.

Monitoring the turning on and turning off of a single gene in real time has proven to be a significant challenge in biology. Our team has chosen to use the pGLO® plasmid system in Escherichia coli as a tool to observe the speed at which a synthetic gene can be both activated and inactivated in a living cell using fluorescence monitoring techniques. We postulate that the framework we develop will assist others in analyzing the behavior of both natural and synthetic genes in other organisms. Further, we are the first group to characterize the kinetics of this genetic system used in educational and research laboratories across the world.

KEYWORDS: Fluorescence, Gene, Genetic Circuit, Synthetic Biology, Kinetics, Chemistry

CONTACT: Dr. J. Kenneth Wickiser, MADN-CHM-LS, USMA, West Point, NY 10996
Email: john.wickiser@usma.edu TEL: 845-938-5813

Towards A Constitutive Time Dependent Model for Validating Nanomechanical Properties of a Single Neuron

Patrice Benson, Ph.D. and Anthony N. Johnson, Ph.D., USMA and Daniel P. Cole, Ph.D. and Stephen Wilkerson, Ph.D., ARL

A constitutive model is proposed to validate the nanomechanical properties and behavior of a single neuron under time dependent loading. The goal of the model is to corroborate empirical findings which measures nano size forces (nN) acting in response to the deformation of neuronal somata by various loading apparatuses to include a Polystyrene bead and an Atomic force microscopy (AFM) probe for point loads. The mechanical data derived from the model is intended to analyze the cell response to both large and small deformations and is cast within the framework of the standard concepts of modern continuum mechanics. Implementation will be via a user-defined geometry, material, and boundary subroutine in COMSOL. The shape of the cell body (soma) led to an axisymmetric representation which was utilized for modeling the various probes as well. Other simulated neuronal responses were measured including stress, strain, and material degradation.

KEYWORDS: Neuron, Cell Mechanics, Constitutive Modeling, Finite Elements, Interpolation

CONTACT: LTC Anthony N. Johnson, USMA, West Point, NY 10996
Email: anthony.johnson@usma.edu TEL: 845-938-2846

Eularian Modeling of Hollow Cone Sprays

Dr. Luis Bravo and Dr. Chol-Bum Kweon, ARL and Thomas Nelson, Dr. Michael Benson, and Dr. Bret Van Poppel, USMA

This work examines a Computational Fluid Dynamics (CFD) approach to provide temporally resolved simulations of a novel pressure swirl atomizer presently studied at Stanford University [1]. In a pressure swirl atomizer, the liquid spreads out to form an air-cored vortex within the nozzle and an emerging thin annular film. Due to instabilities the film breaks up to form a hollow cone spray. The numerical simulations focus on the near field nozzle flow physics and primary atomization of the spray. An incompressible flow formulation is adopted with a geometric unsplit Volume of Fluid (VOF) method to track the interface between two immiscible fluids in interfacial flow simulations. Here, the interface is modeled via an advection equation implicitly tracked using a discrete indicator function, f, with values representing the volume fraction of the tagged fluid within a cell. An Adaptive Mesh Refinement (AMR) scheme is also employed to efficiently capture the shear layers near the liquid-gas interface. The study is carried out for atomizers in the range of 2mm and 3mm diameters at intermediate Re = 2.6-3.9x103, We= 0.11-0.17x105. An in depth comparison is then provided between the CFD results and measurements obtained via shadowgraphy and CT scans. [1] P.A. Vazques, J. Eaton, R. Fahrig, et al, ILASS, 2014.

KEYWORDS: Computational Fluid Dynamics, Volume of Fluid, Atomization

CONTACT: Dr. Luis Bravo, ARL, APG, MD, 21005-5069
Email: luis.g.bravo2.ctr@mail.mil TEL: 410-278-9525

A CIP Study of UHPC

CDT Brad Brownfield and CDT Ian Williams, USMA

Ultra high performance concrete is a mixture of Portland cement, silica fume and silica flour, silica sand, water and high-range water-reducing admixture. The proportions of the ingredients are chosen to optimize the hydration process, and particle packing. Typical compressive strengths for UHPC are on the order of those for mild steel. The weak link in the resulting product is the macroscopic voids that remain even though the mixture flows and is consolidated through vibration. The goal of this research was to try to adapt processing technologies for ceramics in a fashion that would reduce the void ratio in the UHPC. Of the three types of pressing used in the production of ceramics, cold-isostatic pressing (CIP) was chosen, primarily because the available equipment for warm- and hot-isostatic pressing utilizes temperatures beyond the range normally used in curing UHPC. Densities and compressive strengths for specimens treated with a variety of pressures will be presented, along with recommendations for future research.

KEYWORDS: Cold-isostatic pressing, ultra high performance concrete, density, ultrasonic mixing, particle-size distribution, particle packing, void space, microscopy

CONTACT: DR Chris Conley, DCME, USMA, West Point, NY 10996
Email: christopher.conley@usma.edu TEL: 845-938-4092
Steve Kilczewski, WMRD, ARL, APG, MD 21005
Email: steven.m.kilczewski.ctr@mail.mil TEL: 410-306-0952

The Role of the Windlass in Improvised Tourniquet Use on a Manikin Hemorrhage Model

CDT Matthew P. Altamirano, USMA and John F. Kragh, Jr., MD, James K. Aden, III, PhD, and Michael A. Dubick, PhD, USAISR

In emergencies when commercially designed tourniquets are unavailable, hemorrhage may need to be controlled with improvised tourniquets. In the aftermath of the Boston Marathon bombing, no improvised strap-and-windlass tourniquets were used to treat casualties; tourniquets without windlasses were used. The purpose of the present study is to determine the effectiveness of improvised tourniquets with and without a windlass in order to better understand the role of the windlass in tightening the tourniquet strap. An experiment was designed to test the effectiveness of improvised strap-and-windlass tourniquets fashioned out of a tee shirt on a manikin thigh. Two users conducted 40 tests each with and without the use of a windlass. Without a windlass, improvised tourniquets failed to stop bleeding in 99% of tests (79/80). With a windlass, improvised tourniquets failed to stop bleeding in 33% of tests ($P < 0.0001$). In tests with no windlass, attempts to stop the pulse completely failed (100%, 80/80). With a windlass, however, attempts to stop the pulse failed 31% of the time (25/80); the difference in proportions was significant ($P < 0.0001$). Improvised strap-and-windlass tourniquets were more effective than those with no windlass, as a windlass allowed the user to gain mechanical advantage. However, improvised strap-and-windlass tourniquets failed to control hemorrhage in 33% of tests.

KEYWORDS: First Aid, Damage Control, Hemorrhage, Shock, Makeshift, Homemade

CONTACT: CDT Matthew P. Altamirano, USCC, USMA, West Point, NY 10996
Email: matthew.altamirano@gmail.com TEL: 858-345-7894