Presentation Abstracts

3-D Imaging of Internal Mechanics of Undercarriage Explosions Using X-ray Radiation Exposure

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An establishment of the requirements and dimensions necessary to expose a buried explosion to X-ray radiation for the purpose of creating 3-Dimensional representations of the explosion is presented. In preparing for the experiment, details of the explosive composition, soil characteristics, and explosion attributes were recorded, as well as the building of a rigging system to test the different variables of the experiment. Construction of the X-ray imaging device was mission essential and was completed though establish power to the X-ray Emitters, completing all three rings of the device, and preparing the device and its components for testing. By exposing the explosion to X-rays in multiple planes, it allows the combination of multiple X-ray images into one 3-Dimensional image. This experiment creates a method for analyzing inside undercarriage explosions during the earliest stages of the explosion to better define and predict the direction and force of a blast created by buried ordnance.
KEYWORDS: Undercarriage Explosion, X-ray Radiation, 3-Dimensional Imaging, Buried Ordnance
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A SYSTEM OF SYSTEMS: DENSE URBAN ENVIRONMENTS

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The former Chief of Staff of the Army (CSA), GEN Raymond Odierno, identified megacities and dense urban areas as an important potential future operating environment for the US Army. Several years of analysis by the CSA's Strategic Studies Group determined that current doctrine is inadequate to conduct full spectrum operations in a dense urban environment, especially in a megacity, where populations exceed 10 million people. Historical doctrine has been based on the idea that the Army should avoid direct action in urban areas, bypassing them to achieve their objective. In the modern world, bypassing dense urban areas will be difficult as they are increasingly becoming the center of gravity in terms of economics, politics, demographics and culture.

This project reviews and builds upon Cadet Matthew Benjamin's summer internship in which he identified socio-cultural data analysis and visualization as two key problems facing commanders in a dense urban environment and connects his project to the wider community of interest organized by ARL. Dense urban environments are extremely complex due to their scale, multidimensionality, interconnectedness and uncontrollability. Layered on top of this complexity, is the wicked complex nature of socio-cultural data, which is difficult to model, difficult to visualize and has the potential to quickly overwhelmed commanders

on the ground. This project proposes the need for a common operating picture of dense urban areas that overlays socio-cultural data on existing physical data to help increase situational awareness and identify potential "hotspots" where increased attention would be required.

KEYWORDS: Megacities, Socio-cultural Modeling, Socio-cultural Data Visualization, Situational Awareness

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Using MapReduce to Detect Anomalies in the Real-Time Smart Grid

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Modern power grids quickly distribute electricity across large geographic areas with a high level of reliability. However, they are not invulnerable to widespread failures. In occasions of hardware failure, or fault (such as a transmission line tripping) the system can operate in a sub-optimal state and result in a loss of electric power to some customers. These events require grid operators to locate the point of failure in order to resolve the problem, a process which can take minutes or several days in large cascading blackouts. In recent years, engineers have explored ways to automate the rerouting process so that the grid can regulate itself. One such proposed system is the Real-Time Smart Grid, which seeks to monitor the vitals of a power grid in real-time. In this paper, the anomaly detection software components of the Real-Time Smart Grid is described. The solution proposed here incorporates the Phoenix++ MapReduce framework to process the large amount of data constantly produced by the grid in parallel. The algorithm enables the Real-Time Smart Grid to detect anomalies rapidly, provide data to automated controllers, and notify grid administrators of the location of any points of failure. This can enable grid operators to analyze and mitigate potential issues and concerns in a matter of seconds.

KEYWORDS: Real-Time Smart Grid, MapReduce, Detect Anomolies, Power Grid

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Anomaly Detection of Cyber Physical Systems

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Cyber-Physical Systems (CPS) are integrations of physical systems and or processes, networks, and embedded computing/control. The Smart Grid concept is an example of a CPS. At a high level, the smart grid is made up of physical components of the power grid (physical system), communication networks for data acquisition and control (networks), and automated/manual control (computing/control). All components of CPS are tightly coupled and proper analytical techniques are critical in the design and operation of CPS. Historically, on-line analysis and operation of power grids relied on a number of assumptions related to the interaction of CPS components. For example, modeling of networking latency/timing of data coming to a power grid control center has often been neglected in regards to state estimation and decision making due to the temporal scale difference between communication systems and the power grid. While this approach has worked well in the past, it resulted in a conservative operation of the power grid and may not be suitable as there is more customer participants within the power grid (e.g. an increase in demand response participants and distributed generation facilities). USMA and ARL are collaborating to initiate a Davies Fellow program with a primary goal of participating in a three to five year investigation of anomaly detection in CPS. Anomalies of interest could be issues with the physical system (e.g. transmission line tripped or damaged), cyber system (controller malfunctioning, or compromised), or the communication network (data integrity issues). Specific power system applications to be studied are wide area measurement and control (WAMC) applications of demand response (DR), volt/VAR control, and cyber-physical state estimation (SE) within a smart grid framework. Functional testbeds of CPS systems presently exist at the United States Military Academy (USMA) and the United States Naval Academy (USNA) that will be leveraged for this effort.
KEYWORDS: cyber physical system (CPS), anomaly detection, state estimation, demand response
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The Fractional Mathematics of Networks: an Inquiry into *Tomorrow's Science*

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Studying the historical interactions of science and mathematics reveals that revolutionary changes in one field lead to great changes across all STEM disciplines. Such changes are afoot today as applied mathematical theories are integrated into the theories of complex systems and network science, offering broad insights throughout all of science. With this in mind, I will examine the possibility of synthesizing fractional mathematics and network science in order to bring about a more universal understanding of complexity.
KEYWORDS: Complexity, Fractional Calculus, Network Science, History of Science
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Palladium and Platinum Square Hollow Nanotubes for Catalysis

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High aspect ratio nanotubes were synthesized using square planar salt precipitates as a template. Template formation was examined as a function of square planar complex ion type and concentration. Salt templates were reduced in solution using a range of reducing agents with different resulting morphologies. Nanotubes were analyzed using scanning electron microscopy (SEM), energy dispersive X-ray analysis (EDX), and X-ray diffractometry (XRD). Nanotubes are envisioned for use in hierarchical nanotube-nanowire assemblies for lightweight energy storage and catalytic materials.
KEYWORDS: Nanowire, nanotube, 3-dimensional porous materials
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A simple of 5x7 array of cubical buildings, with one building in the center column twice as tall as the others was measured for a flow representative of a fully turbulent atmospheric boundary layer. The measurements were made in a water channel and represented a near-scaled replication of experiments done using the Environmental Protection Agency wind tunnel in the early 1990's with applications to an urban environment. Both the full three-dimensional time averaged velocity field and concentration fields were measured in over 13 million voxels to provide a detailed data set sufficient to validate a broad variety of computational fluid dynamic codes and solvers. The measurements leveraged the capabilities of a Magnetic Resonance Imaging apparatus to non-intrusively sample the domain, which consisted of a main flow sweeping over the buildings as well as a low velocity scalar contaminant ejected through the channel floor in the wake of the single tall building in the array.
KEYWORDS: Contaminant Dispersion, Urban Flow Measurements, MRV, MRC
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Machine-Generated Cyber Maneuver

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The application of a traditional software system development process to achieve the goal of a machine-generated cyber maneuvers is presented. Achieving the capability of machine-reasoned maneuvering is needed to design and execute maneuvers at machine speeds, overcoming human limitations to decide and act in a timely way. Other benefits of this approach include accounting for dynamic operational context and coordination with multiple simultaneous maneuvers in cross-domain operations. At the heart of this design is a general-purpose, holistic model, not limited in scope to any specific mission, and one that will further develop through evolution. In this model of cyber operations, maneuver is only one component developed in context of others, each comprehended as intimately interconnected and understood by reference to the whole. In addition to maneuver, development of model components such as targeting are pursued in parallel. Inspiration for the software system is taken from existing maneuver practice and concepts.

KEYWORDS: Cyber Operations, Machine Reasoning, Maneuver, Targeting, Software Component Model

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Reduced-Order Models for Engine Fuel Penetration in Mixing-Limited Vaporization

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The objective of this research is to establish a reduced-order method (ROM) for liquid length engine scaling analysis and to assess its validity over ranges relevant to Army reciprocating engines. The ROM framework is based on a mixing-limited vaporization model [1], heat and mass transfer principles, and provides a reduced method to perform engine scaling. It also provides the ability to simulate various hydrocarbon fuels of interest, including n-dodecane, cetane, and tetradecane, as well as the ability to construct a JP-8 mixture based on the mean evaporation constant (MEC) method. The results are then vetted against measurements, as well as 3D-CFD simulations for various cases of interest. The cases include an evaporating single-plume spray, and a single-cylinder moving piston case [2] for comparison. Finally, the simulations are visualized employing a recently adopted immersive visualization technology, zSpace, to highlight the three-dimensional fine details. *[1] D. Siebers. SAE 1999-01-0528, 1999; [2] Scarcelli, R., et al., SAE Technical Paper 2016-01-0593, 2016*

KEYWORDS: Engine scaling, ROM, MEC, 3D-CFD, zSpace, Visualization

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Radioisotope Power Source for Unattended Sensors

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Using beta-radiation from radioisotopes to provide power for isolated sensors with low power requirements. These sensors could be placed in remote locations and be powered without resupply missions for years at a time. There are two approaches to doing this, a direct method and an indirect method. The direct method simply involves the use of beta-voltaic cells to convert the beta-decay energy into electrical energy. The indirect method involves the use of a phosphor to absorb a portion of the beta-radiation and reemit it in the form of light. The light energy along with the remaining beta-radiation is captured by a beta-photovoltaic cell. These two methods are being improved upon and evaluated for efficiency.
KEYWORDS: Radioisotope Power Source, Unattended Sensors, Phosphor, Beta-Voltaic Cell
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Simulating Rubber Under Impact: Pseudo-Elastic Model vs. Viscoelastic UMAT

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Many of the material models provided by commercial finite element analysis (FEA) software lack the ability to accurately predict the response of rubber under arbitrary three-dimensional loading. Two material models are compared, using the high-fidelity FEA software LS-DYNA. Using data from drop tower tests, a "pseduo-elastic" rubber model available in LS-DYNA's built-in material library is compared to a user-defined material model (UMAT) calibrated using third-party software from Veryst Engineering. It is demonstrated that for most applications dealing with impact loading the extra accuracy provided by the nonlinear-viscoelastic UMAT does not outweigh the increased computational cost. Challenges associated with using the third-party software on DoD High-Performance Computers (HPC's) are also discussed.
KEYWORDS: Rubber, LS-DYNA, PolyUMod, Finite Element, Impact
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Energy Imbalance Calculations of Weight Gain in the Military

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Post-service military lifestyle often leads to a reduction in physical activity and increased weight gain. Similar to results from athlete detraining studies, reduced physical activity is associated with accretion of fat mass. Unfortunately, weight gain and obesity has been well correlated to comorbidities such as type 2 diabetes, high blood pressure, and poor lipid panel results. Therefore, determining a calculation of energy imbalance in post-service military personnel is important for developing reasonable physical activity and diet recommendations to prevent weight gain. Through published weight change data in post-service military applied to a validated thermodynamic energy balance model, we estimate this energy gap. We then translate this energy gap into energy intake/expenditure recommendations needed to mitigate the observed weight gain.
KEYWORDS: Weight gain, post-service military, energy balance, first law of thermodynamics
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Connections between the geometry of Grothendieck-Springer resolutions and the isospectral Hilbert scheme

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The (Grothendieck-)Springer resolutions are foundational and important objects in representation theory and algebraic geometry. I will give the construction known as filtered quiver representations and use that to construct the Hamiltonian reduction for the Borel setting using a framed 1-Jordan quiver. The geometry in this nonreductive setting is closely related to an object known as the isospectral Hilbert scheme, which could be thought of as the set of n ordered points on a complex plane. If I have time, I will discuss Cherednik algebras and their connection to the quantization of the Hamiltonian reduction setting. This is joint with 2nd Lieutenant Lisa Jones.
KEYWORDS: Hamiltonian reduction for the Borel, isospectral Hilbert scheme, Grothendieck-Springer resolutions
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Now You See Us – Now You Don't: Community Detection in Multilevel Networks

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Individuals today maintain personas in a multitude of social networks ranging from online social media networks to offline collaboration networks and multiple networks in between. These networks are hardly disjoint and exhibit significant overlap, where a relationship in one network may increase the likelihood of and dynamics of a relationship in another network. In some social networks, relationships are readily apparent, where in other social networks they remain hidden. Multilevel social network data is collected on twelve different faculty departments of a small university in North America. Network data includes publicly available data such as co-authorship and website co-occurrence as well as private data such as file sharing and access permissions. Several community detection approaches are applied to each network to include Clausset-Newman Moore, Clique Percolation, Truss, and Order Statistics Local Optimization Method (OSLOM). Co-clustering across social networks and community detection approaches are investigated. Tradeoffs between computational efficiency, consistency, discriminability, modularity, and intuition are provided. Recommendations are provided based on application, ranging from detecting social engineering attacks on file sharing networks to the study of organizational behavior.
KEYWORDS: collaboration networks, social networks, dynamic modeling, community detection, clustering, clique percolation, organizational behavior
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Predicting the NHL Playoffs with PageRank

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Applying Google's PageRank algorithm to sports is a popular concept in contemporary sports ranking. However, there is limited evidence that rankings generated with PageRank methods do well at predicting the winners of playoffs series. In this paper, we present a new ranking method and predict the outcomes of the 2008-2016 NHL playoffs. Our method modifies the original PageRank algorithm by incorporating cumulative margin of victory between pairs of teams into an adjacency matrix and Corsi statistics into a personalization vector. Unlike previous studies which focus primarily on different ways to code adjacency matrices, we focus on a new approach for defining the personalization vector. We found our ratings had a 70% accuracy for predicting the outcome of playoff series over a nine year period. Our method outperformed the Colley, Massey, Bradley-Terry, Maher, and Generalized Markov methods by 5% over the entire time period and was at least 60% accurate in every season. The implication of our results is that PageRank based models may have untapped potential that can be realized by experimenting with different ways of defining the personalization vector.
KEYWORDS: Markov Chains, National Hockey League (NHL), Corsi Statistics
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Ultra High Performance Concrete Pore Reduction through Pressurization

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It is hypothesized that the reduction of pores in ultra-high performance concrete (UHPC) through pressing will increase the strength and durability of the UHPC. Thirty-six cylindrical green pucks of 13 mm diameter were pressed to different pressures using uniaxial and cold-isostatic presses (CIP). These pucks were then characterized by density, using geometric calculations and a helium pycnometer. Porosity and compressive strength were determined using a micro-computed tomography (micro-CT) and a universal testing machine, respectively. There was an increase in compressive strength and density as the pressure increased, although past 50 ksi and10 ksi, respectively, the data is inconclusive.
KEYWORDS: Ultra High Performance Concrete (UHPC), Pore, Pressure, Particle Size, Concrete
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Structural Analysis of the Army Mission Essential Task Network

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As the Army continues to place overwhelming training demands on units, it is imperative that commanders prioritize training efforts. A 2015 War College study titled, “Lying to Ourselves: Dishonesty in the Army Profession” documents a recent trend of commanders falsifying training proficiency reports. Consequently, the Army has initiated a new reporting standard called “Objective-T” which establishes a framework to objectively evaluate training. This new standard aims to improve the quality of training evaluations, but it comes at a cost. Units are now held to a more rigorous evaluation system that requires commanders to devote time and personnel toward maintaining detailed training records. The increased reporting burden means that commanders must be even more careful when considering what tasks to emphasize. Our research seeks to apply network science methods to assess the structural importance of specified Mission Essential Tasks (MET) that reside on the Army Training Network. These METs from a complex web and the relationships between tasks can be modeled as a directed network. By taking a more holistic view of the network we hope to identify simple solutions that capitalize on transitive ties and second order effects. Once we complete a structural analysis of the network, we hope to implement our method into a python-based software tool.
KEYWORDS: Network Science, Army METL, Centrality, Data Science
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Tissue engineered aligned fiber scaffolds for repair of the nervous system (The SENSA Project)

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In the U.S. and in military operations overseas, over 100,000 traumatic injuries occur that affect the nervous system each year, while an additional 85,000 limbs are amputated. The current gold standard of treatment for repair of gaps exceeding 3 cm is the transplantation of autologous nerve graft. However, despite modern surgical techniques, acceptable restoration of function is only achieved in 50 % of cases, and is accompanied by donor site morbidity. Furthermore, current neural-interfaces do not adequately provide sensory feedback from prosthetic devices, which limits fine motor control. Accordingly, there is great clinical need for tissue-engineered conduits that guide and regulate regenerative axon growth following trauma to the nervous system.

Here, we developed tissue engineered scaffolds consisting of multiple aligned collagen fibers. Individual fibers were formed by extrusion of type 1 bovine collagen through a 27 gauge needle to form 10 cm x 20 μm fibers. Arrays of 50 – 200 fibers were fastened together with suture at 2 cm intervals and cut into individual conduits. Free conduit endings were tethered to petri dishes using silicone glue, after which conduits were crosslinked and sterilized in genipin and ethanol. Single DRG explants from E7 white leghorn chickens were seeded within conduits at one of the sutures and cultured 7 – 14 DIV. Alternatively, an organotypic model consisting of adult mouse spinal explant was used to guide regenerative growth through peripheral nerves prior to integration with conduits. Following culture, neurons were stained for βIII-tubulin and Nef-H and whole mounted for confocal microscopy. Panoramic images of axons were traced from the distal end of each axon towards the nuclei using NeuronJ for quantification of outgrowth. The development of nerve conduits composed of longitudinally aligned matrices represents the next step in guidance of axons following injury. The techniques presented here show that axons attach and extend within a fiber conduit. In vivo, these conduits may be directed to distal degenerating nerves in place of autografts, or may be integrated with electrode arrays for neural-prosthetic interfacing.

KEYWORDS: Oganotypic, genipin, axons

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A Vertex Cover Algorithm for A Directed Graph

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The problem of determining a minimum vertex cover is NP-hard. In this work, an algorithm to approximate such a cover for a directed graph is presented. The input for the algorithm is the adjacency matrix for a graph, thus, it is applicable to an arbitrary directed graph with the caveat that larger graphs will have a longer run time. For the purpose of visualization, the algorithm is demonstrated on a small set of problems with known solutions. Then, the algorithm is applied to a subset of the tasks in the Army Training Network to approximate the solution to a minimum vertex cover for the purpose of identifying tasks that commanders should prioritize when allocating scarce resources such as time and money. The algorithm contains several important abilities. (1) Users are allowed to specify an arbitrary subset of vertices that must be contained in the vertex cover. In the context of the application of the algorithm considered in this work, this equates to a commander having the ability to specify that certain tasks must be completed regardless of whether or not they would be selected in the optimal vertex cover. (2) Users are allowed to assign weights/costs to each vertex. In the context of the Army Training Network, this equates to having the ability to specify the time or monetary cost associated with selecting a task to be completed. Advantages and disadvantages of this algorithm compared to other vertex covering algorithms are discussed.
KEYWORDS: Graph theory, vertex cover, maximum independent sets, and algorithm.
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Open Questions: Software Defined Networks for Tactical Networks

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We are studying the applicability of the Software Defined Networks (SDN) paradigm to large-scale military tactical networks. SDN promises to deliver higher levels of network adaptability, improved resource utilization, scalability, redundancy, and security. The current SDN paradigm is focused on enterprise networks, where secure, reliable, and high speed connectivity are assumed. In the tactical network scenario, however, none of these assumptions may hold. There are many open questions regarding the applicability of SDN to tactical networks. In particular, limited bandwidth and frequent loss of connectivity may pose difficult challenges to this new networking approach. To address these open questions, we are engaging in a preliminary study of SDN in tactical environments by designing experiment scenarios, with emphasis on the inherent constraints of military networks. The developed scenarios and use cases will be deployed within the Network Science Research Laboratory's (NSRL) SDN experimentation platform to assess the performance and limitations of an SDN network characterized by centralized network controllers managing distributed forwarding devices. The results of these experiments will provide guidance regarding potential areas where the SDN paradigm can be enhanced to mitigate its deficiencies and make it more beneficial to the tactical networking space.
KEYWORDS: Software Defined Networks, Tactical Networks, Network Emulation, SDN, SDN Controllers
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Early Synthetic Prototyping

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In order to streamline the acquisitions process for the Army, RDECOM's Early Synthetic Prototyping project is presented. Game analytics are used in order to process mass amounts of data created by crowdsourcing small-unit and higher echelon strategy video games using in-game synthetic prototypes. The ultimate goal is that the Army's acquisitions process can draw influence from the tactics and synthetic prototypes used by players both inside and outside of the Army.
KEYWORDS: Game analytics, Early Synthetic Prototyping, acquisitions, crowdsourcing
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Using RT-qPCR as a Quantitative Assessment of Seasonal Affective Disorder

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In this project three organizations at West Point including BS&L Department, the Photonics Research Center, and Center for Molecular Science collaborate with scientists at the Karolinska Institute in Stockholm, Sweden, and the Rockefeller University in New York City. The goal of the team is to assess whether p11 levels in cadets' peripheral blood correlates with depression and whether any observed correlation is seasonal. The winter atWest Point is nicknamed the "Gray Period" to describe both the weather and the mood of the cadets during that time. In this study, the correlation between light spectrum and intensity data and p11 levels will determine the validity of the "Gray" or "Gloom" Period and if its effect on cadets has a biological basis. The Photonics Research Center has measured ambient light data at different locations on West Point in Cadet Area to correlate the relationship between the light data and depression. The BS&L department enrolled cadet volunteers to take the BDI-II and Zung surveys for depression and consent to have their blood drawn for p11 analysis over the course of a semester. The Center for Molecular Science in the department of Chemistry and Life Science processes the blood samples and conducts blood work to separate the layers of blood into peripheral blood mononuclear cells (PBMCs), Plasma, and red blood cells.
KEYWORDS: p11, depression, seasonal affective disorder, qPCR
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An Unsteady Two-Dimensional Complex Variable Boundary Element Method

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The Complex Variable Boundary Element Method (CVBEM) is extended to applications in modeling time-dependent potential problems governed by the Laplace equation. Typically, CVBEM applications have been limited to approximating solutions to steady-state problems, however, by coupling a CVBEM-type approximation series with a generalized Fourier series, unsteady transport problems can be modeled. The modeling procedures presented can be applied to approximate the solution to any boundary value problem governed by the Laplace equation, however, the specific application considered in this work is a problem related to modeling unsteady heat transport. The underpinning of the new technique is to decompose the global problem into two sub-problems; namely, a transient and a steady-state sub-problem. The sum of the Fourier series solution to the transient component of the problem and the CVBEM series solution to the steady-state component of the problem is the solution to the global boundary value problem. The mechanics and solution success of this new technique are demonstrated and discussed.

KEYWORDS: Complex Variable Boundary Element Method (CVBEM), Laplace equation, time-dependent, numerical solutions to partial differential equations, potential problems, flow nets.

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Pilot Testing on the Physiological and Biomechanical Effects of Varied Trunk-Pelvic Load Distribution

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The purpose of this research study was to evaluate and measure the physiological effects on the body when a set load is distributed between the trunk and the pelvis. The duration of my time working on the project was spent during the developmental portion when the specific procedure and methods of collecting data were still being solidified for the actual research. The procedures and methods were evaluated, adjusted, and verified through an extensive pilot testing program. During this pilot testing, all of the various data collection systems and pieces of research equipment were tested and validated over the course of multiple trials conducted in the same manner in which the research was set to be conducted. The Cosmed system, Instrumented Treadmill, Isokinetic Dynamometer (Biodex), and other tools and pieces of equipment used in this study were specifically designed and/or adjusted throughout the duration of the pilot testing to best meet the exact goals of the researchers. Being the first project to ever study the physiological and biological effects of trunk-pelvic load distribution, the procedures and methods used are the first of their kind. The extensive pilot testing conducted to validate these procedures and methods was crucial to the development of the foundation of this research.

KEYWORDS: Trunk Load, Pelvic Load, Pilot Test, Cosmed, Biodex, Load Distribution

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ALCAMP: A Pathmapping Algorithm and its Applications in Defense

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Many research questions related to defense concern spatial paths, for example those physically traveled by humans on foot or in vehicles, or those traveled by a cursor across a computer screen as a human interacts with software. Comparing paths is notably difficult because those produced in naturalistic tasks are often highly complex, and contain features, like self-intersections and loops, to which other mapping algorithms are not robust. We present the Algorithm for finding the Least Cost Areal Mapping between Paths (ALCAMP), and discuss both prior research and future directions using this algorithm to solve defense-related problems. ALCAMP, coded in the R Statistical Computing Language, computes an optimal mapping between two paths by connecting points on each path to points and segments on the other. The area of the resultant polygon serves as a measure of divergence between the two paths. We describe prior research using ALCAMP to compare computer cursor movements, walked and flown paths, and traveled versus recalled paths, as well as current human-robot interaction research. In addition, we describe a more advanced technique in which multidimensional scaling is used to construct a similarity space that can be clustered to permit the inference of consensus among agents. Finally, we propose future applications pertinent to defense, such as measuring formation and path adherence, testing the repeatability of navigation algorithms and the clarity of communicated navigation instructions, inferring shared mental models for navigation among members of a group, and detecting anomalous movement in manned and unmanned systems.

KEYWORDS: Path Mapping, Algorithm Development, Human-Computer Interaction, Human-Robot Interaction, Comparing Paths

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Cascading failures in complex networks

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Networks are at the core of modern society, spanning physical, biological and social systems. Each distinct network is typically a complex system, shaped by the collective action of individual agents and displaying emergent behaviors. However the interdependence of individual agents on one another can lead to unanticipated consequences. Propagation of an initial local failure through the system, a cascading failure, can lead to substantial loss of network's interconnectivity and functionality. Therefore cascading failures remain a major threat to the reliability of network-like infrastructure such as power grids, public transportation systems or financial markets.
Simple mathematical models can provide important insights into such phenomena. In this talk, I will discuss several such models, beginning with properties of node percolation in an individual network, then moving on to modeling cascading phenomena in interdependent networks. With the help of a classic model of cascading failures, the BTW sandpile model, I will illustrate the spread of failures in a system of interdependent networks and I will discuss the role that interlayer connectivity has on promoting or suppressing large cascades.
KEYWORDS: cascading failures, complex networks, sandpile model, interdependent networks
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Development of a predictive model from a simulated artificial clostridium fermentation towards real-time culture monitoring

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In previous work, Raman spectroscopy together with statistical modeling was shown to be effective for real-time data acquisition of consumable sugar (glucose) and accumulating products (butyric acid, acetic acid, and butanol) in a clostridial fermentation culture. Developed partial-least squares (PLS) models were applied to both agitated and static cultures with the former showing preferred modeling parameter values (R2Y = 0.99 and Q2Y = 0.98). Model outputs were shown to be comparable to off-line analyzed data from traditional HPLC for new clostridial experimental data through cross-validation. In this study, a bottom-up approach is employed where experimental data from HPLC analyzed data for reaction components is used to simulate an artificial fermentation culture devoid of cell activity. Raman spectra of corresponding reaction components; (i) glucose, (ii) butyric acid, (iii) acetic acid, and (iv) butanol, in specified proportions were acquired for corresponding time points. The acquired spectra together with known concentrations of reaction components were used to build new sets of PLS models. These new models will be compared with original models created for the actual clostridial fermentation for model performance with both sets of models executed in real-time.
KEYWORDS: Raman spectroscopy, chemometrics, MVDA, predictive modeling, clostridium, fermentation, real-time monitoring, bottom-up approach

Poster Abstracts

Understanding Cyber Defender Knowledge Representation and Reasoning Processes Using Ontological and Cognitive Modeling

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Analytical capabilities of the human decision maker are needed and are indispensable when ensuring the security of any cyber infrastructure. It is the human abilities to integrate information, to reason, to learn and to quickly adjust to changes that make such significant contribution to cyber defense. The understanding of these processes and the ability to automate them, relies on integration of knowledge from human cognitive theories on reasoning and knowledge representation technologies. In this research I develop a holistic approach for understanding and simulating human decision making in knowledge-intensive tasks such as cyber defense. To this purpose, the study integrates semantic information representation together with a cognitive model of decision making into a hybrid computational architecture. With respect to semantic knowledge representation, a packet-centric ontology was developed to represent core components of network traffic. The ontology is used to describe real-world network traffic, including adversarial port-scanning. This ontology also serves as a basis for higher level ontologies developed as part of ARL Cyber-CRA for cyber operation, threats and risks. Then, the study investigates the combination of a packet-centric ontology with an adaptive cognitive agent that has learning capabilities. This combination is used to understand the human defender reasoning processes when monitoring network traffic. Simulation experiments evaluated the ability of the proposed hybrid computational architecture to successfully detect malicious port scanning within legitimate network traffic. Findings indicate that the benefit of pairing cognitive agents and ontologies goes beyond the ability to gauge into the decision making process of the human analyst. Such combination can serve as an initial step towards the development of cognitively inspired detection aid tools that adapt to threats and automate some of the tasks currently performed the cyber defenders.
KEYWORDS: Cyber defense, Decision making, Cognitive modeling, Computational ontology
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Ignition of Energetic Materials from an Electrostatic Discharge

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Ignition and combustion experiments were conducted using small quantities (5-10 mg) of five different energetic materials. The energetic materials were analyzed using an electrostatic discharge (ESD) system with a viewing window for advanced diagnostics to measure temperature, energy generation, and emission spectra of the reactions. A two-color high speed camera pyrometer was used for calculating the spatially and temporally resolved temperature of the electric spark-induced combustion. A gated high-resolution, broadband spectrometer (200-1000 nm) was used to compare emission features of the spark with and without energetic materials and calculate the temperature of the spark. Infrared and visible photo receivers were used to measure the time-resolved optical emission for calculating the optical energy generation of the energetic materials. The results show the ignition sensitivity, emission features, and spark and combustion temperatures of RDX, TNT, PETN, PBXN-5 and CL-20 from an electric spark at different energy levels ranging from 0.25 J to 10 J. The spark-induced combustion was compared to previous results from laser-induced deflagration reactions.
KEYWORDS: Electrostatic Discharge, Energetic Materials
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The Effects of High Energy Lasers on Rotating Steel Drums

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High Energy Lasers (HEL) are extremely effective in delivering energy to stationary metallic targets. However, a rotating target poses different questions as to the heating patterns and effectiveness of the laser. One of the major obstacles is affixing temperature measuring devices to a rotating object while still receiving real-time data. The typical solution to this problem is to use slip rings or contact brushes, but both these solutions introduce significant amount of noise into the measured signals. Our solution to this complex and little researched problem was to design a Data Acquisition System (DAQ) using wireless local area network (WLAN) through a secured shell (SSH) network connection. The system consists of eight k-type thermocouples with an Arduino Uno and a thermocouple MUX shield. The Arduino sends the measurements to a Raspberry PI board which relays the real-time data to the monitoring computer over a WLAN connection by means of an Adafruit WIFI Module. With this system, the HEL project was able to achieve a sampling rate of 4 samples per second. This sampling rate was found to be insufficient for the second level of testing with an RDX surrogate placed inside the rotating drum. In order to produce better results, we are redesigning the DAQ by increasing from 8 to 36 thermocouples on a three MUX Arduino Shield. Using Arduino's Analog pins for the ADC, we aim to achieve at least 100 samples per second.
.KEYWORDS: High Energy Laser, Data Acquisition System (DAQ), WLAN, SSH, Thermocouple
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The Importance of Psychophysiological methods in Identifying and Mitigating Degraded Situation Awareness

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Herein we delineate the relationship between poor joint human automation interaction (HAI) system performance and situation awareness (SA) focusing on the effect of system design. Degraded SA is one reason that human users make poor interaction decisions that cause joint system performance to suffer. One key reason for degraded SA is the hierarchical design where the human user is at the apex of the command hierarchy. Within this structure the human user is not able to be fully integrated into the system, which can lead to 'out of the loop' performance issues. We propose that SA could be measured in real time by leveraging psychophysiological methods often used in cognitive neuroscience research. We then discuss a potential framework that could not only identify degraded SA in real time, but could mitigate these degradations. Such a framework would be successful because it would genuinely integrate the human user into the system, essentially closing the loop that underlies joint system failures.
KEYWODS: psychophysiology; human automation interaction; cognitive neuroscience; decision making situation awareness.

Sociometrics of Team Interaction in a Cyber Defense Competition

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In cybersecurity training and research, one aspect that is often overlooked is the human dimension. The purpose of the current study was to use wearable sensors to measure and evaluate interactions among cyber defense teams, and to assess the relationship between these interactions and team performance. Understanding these relationships is valuable for cybersecurity training and for analysis of the teaming process in naturalistic settings. Sociometric Badges were deployed among six cyber defense teams made up of eight members each for the duration of a two-day cyber defense competition. Sociometric Badges (Olguin Olguin, Waber, Kim, Mohan, Ara, & Pentland, 2009) automatically capture human face-to-face interactions (infrared detector), conversational time and vocal features (microphone), physical proximity to others (Bluetooth), and physical activity levels (accelerometer). We analyzed this sensor data, in combination with four performance metrics collected by the competition organizers, to assess the collaborative interactions of the teams in relation to their overall scored performance. Preliminary sociometric analysis suggests that greater face-to-face, speech, and mobility interactions were negatively related to scored team performance. Results are discussed in relation to theories of team formation and the establishment of normative and performance-focused work routines.

KEYWORDS: Cyber security, social network analysis, wearables technology, team interactions, leadership

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Hyperspectral Imaging for In Vivo Detection of Trachea Tissue

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Tracheal intubation involves inserting a tube into the trachea to allow medical procedures such as general anesthesia and ventilation. The process of intubation, however, requires proper insertion into the trachea. However, incorrect insertion into the esophagus occurs up to 23% of all intubation attempts. Devices that can detect esophageal and tracheal tissue could allow a much higher success rate of intubation. Previous research utilizing hyperspectral cameras have shown noticeable differences in the reflectance spectra of esophageal and tracheal tissue at three distinct wavelengths—541nm, 561nm, and 577nm. A prototype utilizing discrete components examining these three wavelengths successfully detected 18 out of 19 trials. Despite the positive results, several issues needed to be addressed, including components being too large for practical use, poor intensity returns when using optical fibers, and the probes not pointed perpendicular to the tracheal wall. This research focuses on a new prototype that points perpendicularly to the tracheal wall while moving the light source and filtered photodetector into the tube to maximize reflectance return. Filtered light will activate photodiodes to generate current allowing a simple logical comparator to determine the tissue type.

KEYWORDS: Tracheal intubation, Reflection spectrometry, hyperspectral imaging

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Topology Design under Adversarial Dynamics

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We study the problem of network topology design within a sequence of policy-compliant topologies as a game between a designer and an adversary. At any time instant, the designer aims to operate the network in an optimal topology within this policy compliant sequence with respect to a desired network property. Simultaneously, the adversary counters the designer trying to force operation in a suboptimal topology. We show the existence of various mixed strategy equilibria in this game and systematically study its structural properties. We study the effect of parameters, and characterize the steady state behavior of the underlying Markov chain. While the intuitive adversarial strategy here is to attack links appearing early in the topology sequence, the Nash Equilibrium strategy is for the designer to defend the earlier links and for the adversary to attack the later links. We validate these properties through two use cases with example sets of network topologies.

KEYWORDS: Network design, Game theory, Topology control
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Streamlining a Military Intelligence Company

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An immense amount of money, time, and care goes in to training the soldiers of the United States Army. In support of such great effort, this thesis looks to streamline the process of selecting, administering, conducting, as well as travelling to and from trainings within the Military Intelligence community. This thesis uses the following three sources: Project Foundry, the Intel Skills STP, and the CATs system. The issue to be resolved is the linkage between the capabilities a company commander needs filled for his unit, the soldiers' designated roles within that unit, and the available schools an individual soldier can go to in order to conduct that training. Linkage between these three aspects does not currently exists. By linking the three pieces, using network science measures, and optimizing for a number of various factors such as money and time to train, we can reduce the number of edges and thus increase the efficiency of the system as it stands today. The applicable goal of this thesis is to be able to make the process of selecting trainings a clearer and less costly decision for a commander.

KEYWORDS: Project Foundry, Military Intelligence, Optimize, Network Science, 35F, Company, Nodes, Edges
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Expansion and Automation of ECO Driving Force for Grain Mobility Calculations

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The energy conserving orientational (ECO) synthetic driving force drives the motion of flat grain boundaries within the timescale of molecular dynamics simulations. This allows researchers to study the mechanisms of grain boundary motion and extract mobility data for a specific boundary misorientation. This work extends the ECO synthetic driving force method from its original implementation for face-centered cubic systems to also include body-centered cubic materials. This expansion of its functionality is the first step in developing a general tool for driving the motion of complex crystalline structures. This work also presents a high-throughput workflow that automates the application of the ECO force to a set of bicrystals models. The workflow allows for more rapid calculations of grain boundary mobility at various orientations and temperatures.
KEYWORDS: Molecular Dynamics Simulations, Grain Boundary, Motion, Driving Force
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LTF Route Planning Services Evaluation

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The Layered Terrain Format (LTF) Route Planning Service, offers small-unit leaders with the ability to obtained optimized, computer-generated routes based on minimizing metabolic costs and exposure to friendly and hostile fields of fire. Collaboration efforts between USMA and ARL HRED-ATSD have resulted in evaluation of the Route Planning Service by USMA and recommendations to improve usability, performance and effectiveness of the tool. The evaluation consisted on the generation of a tactical scenario and analysis of the results returned by the tool. Some of the issues found include inability to work with tree canopies and demand on processing power. The software tool however delivers significant results in the form of optimized routes based on metabolic costs and other units' fields of fire. Although current results are limited and require further analysis by decision makers, the potential to impact how the military conducts its mission planning and preparation in the future is significant. Maintaining USMA / ARL HRED-ATSD collaboration efforts have proven fruitful for the LTF technical development team and should move forward as it serves as a bridge between the Army research community and the end user.
KEYWORDS: Layered terrain format, route planning, software tools, metabolic cost
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Towards Programmable Quantum Networks

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The desire to design and develop reliable quantum networks to support quantum applications has been in the works by mathematicians, computer scientists, and physicists. Encoding of new network abstractions, configuration models is one of the efforts that our group is working to build programmable quantum networks that use unified control plane. We will give some background on programmable networking and OpenFlow protocol, which can manage quantum metadata for teleportation, superdense coding and quantum key distribution. We will discuss our progress towards a unified control plane with secure interactive communication, capable of sending, receiving, and storing packets between various quantum network nodes.

KEYWORDS: Quantum communication system, multi-node classical and quantum network, network topology, teleportation, superdense coding

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ICME Approach for Additive Manufacturing of Novel Metal Powder Feedstocks

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In recent years, additive manufacturing (AM) has attracted substantial interest due to its potential for producing complex parts in near net shape with minimal need for machining. Although straightforward in concept, in that a 3D component is fabricated by the iterative processing of individual layers, the actual production of the component can be quite challenging due to the wide range of material and processing-related factors which must be considered. In particular, it has been shown that the powder feedstock can have a significant influence on the quality of the produced component. Thus, the US Army Research Laboratory has initiated a program to develop novel powder feedstocks tailored specifically for the AM process. This effort will utilize computational methods in conjunction with advanced characterization techniques to evaluate the influence of powder feedstock on the properties and performance of the produced component. Through the use an iterative approach, the feedstock powder will be progressively modified in each iteration based on information and insight gained from the previous effort. It is anticipated that the use of such an approach will result in the rapid development of powder feedstocks optimized for laser based AM processes.

Ballistic Performance of Cross-Laminated Timber (CLT)

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This work describes the research and testing that was done at the Army Research Laboratory (Aberdeen Proving Ground) on the ballistic performance of Cross Laminated Timber (CLT) impacted by a 0.50 caliber Fragment Simulating Projectile (FSP). Data was collected on varying thicknesses of CLT, as well as a single block of plain/unlaminated wood (pine) for comparison. High speed video and x-ray imaging data were acquired and analyzed. Through the use of finite element-based modeling and simulation software (LS-DYNA), a model was created to predict the impact response of a .50 caliber FSP into a CLT panel target. The effectiveness of the model is evaluated by comparing the residual velocities of both the simulations and live experiments.

KEYWORDS: Residual velocity, fragment simulating projectile, finite element method
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Stimulation of regenerative associated genes in chicken dorsal root ganglia neurons (The SENSA Project)

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When somatic tissues are damaged from blast or traumatic injury, spanning peripheral nerves are often disrupted, resulting in gaps between the healthy proximal and distal segments of intact nerve. Immediately after the injury, genes responsible for development and regeneration are temporarily upregulated, enabling a short period of axonal growth. However, as time goes on and the initial stimulus of the injury is removed, gene expression returns to normal levels and regeneration stagnates. One of Project SENSA's goal is to promote continual axonal growth in order to restore complete connectivity between proximal and distal nerve segments. TAA is an experimental drug that has been found to increase the amount of nuclear ribonucleoproteins of rat liver cells, thus inducing liver regeneration. Recent studies conducted by our lab have also confirmed TAA's potential to stimulate axonal growth. The objective of this study was to analyze the effect of the drug TAA on regenerative gene expression in both motor and sensory neurons cultured from chicken embryos. After validating sequence-specific primers associated with housekeeping, developmental, and regenerative genes (ACTB, BRAF, RAF1, GAPDH, and ATF3), two-step quantitative real-time polymerase chain reaction (qRT-PCR) was conducted on the optimized amount of cDNA template of 10 ng. The comparative CT method was used to analyze changes in gene expression between the TAA-treated sample and the untreated control sample. The TAA-treated samples demonstrated a higher level of gene expression than the untreated samples, as indicated by the lower average CT values of 11.8 in comparison to 14.5 for ACTB, and 19.2 in comparison to 22.4 for ATF3. Higher levels of ATF3 gene expression correspond to greater axonal growth, which may be used to promote enhanced regeneration of axons on fiber scaffolds.

KEYWORDS: Ribonucleoproteins, axonal, sensory neurons
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Ultra High Performance Concrete Pore Reduction through Pressurization

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It is hypothesized that the reduction of pores in ultra-high performance concrete (UHPC) through pressing will increase the strength and durability of the UHPC. Thirty-six cylindrical green pucks of 13 mm diameter were pressed to different pressures using uniaxial and cold-isostatic presses (CIP). These pucks were then characterized by density, using geometric calculations and a helium pycnometer. Porosity and compressive strength were determined using a micro-computed tomography (micro-CT) and a universal testing machine, respectively. There was an increase in compressive strength and density as the pressure increased, although past 50 ksi and10 ksi, respectively, the data is inconclusive.
KEYWORDS: Ultra High Performance Concrete (UHPC), Pore, Pressure, Particle Size, Concrete
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Hybrid System Detection & Learning

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Engineers solve varieties of problems to create more efficient processes in a variety of different fields. Solutions to these problems are often groundbreaking leading to new technology, ideas, and successes. However in many situations, these solutions are static and need to be changed to keep up with changing technologies and environments. In this study, I present two different problems in which I have created dynamic solutions relying on the concepts of feedback and control that will adapt with the problem they are solving. A previous study I examined related to the food irradiation industry and the result was a model and an algorithm which provided food with the proper amount of radiation depending on the characteristics of the food. The second study consists of a design of a sensor network to detect enemy drones above a friendly Forward Operating Base. In this design, a lattice of sensors will be launched into the air equipped with an algorithm to constantly adapt to the environment and communicate with each other. This lattice of sensors will combine discrete, continuous, and random sensing techniques to create a hybrid system in order to detect all atmospheric anomalies and prevent any potential adversaries from sabotaging the system. The key element in both of these models is the algorithm and system are learning as time passes by. The algorithm will utilize feedback which means each instance something is sensed, will affect how the sensor reacts to the next sensor. Each sensor will have the ability to control the algorithm to constantly update and react to changes in the environment. This means that they do not need to be constantly updated and are self-sufficient in their respective environments providing a hybrid solution to relevant problems in the nuclear engineering and military fields respectively.
KEYWORDS: Control, Feedback, Sensors, Hybrid System
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Statistical Analysis of Middle School STEM Workshops

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The purpose of this research is to analyze program evaluation data collected from participants in the USMA/ ARL STEM outreach initiatives. The data analysis conducted aims to find correlations and relevant findings in respondents before and after they participate in STEM (Science, Technology, Engineering, Mathematics) workshops. Specifically, the study is looking for a relationship between gender and a desire for a career in a STEM field and an improved confidence level with technology after participating in the workshop. The analysis utilized the Cross Tabulation, Regression Correlation, and Analysis of Variance Methods.

KEYWORDS: STEM, STEM outreach, data analysis, Cross Tabulation, Regression Correlation, Analysis of Variance Methods

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Using RT-qPCR as a Quantitative Assessment of Seasonal Affective Disorder

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In this project three organizations at West Point including BS&L Department, the Photonics Research Center, and Center for Molecular Science collaborate with scientists at the Karolinska Institute in Stockholm, Sweden, and the Rockefeller University in New York City. The goal of the team is to assess whether p11 levels in cadets' peripheral blood correlates with depression and whether any observed correlation is seasonal. The winter atWest Point is nicknamed the "Gray Period" to describe both the weather and the mood of the cadets during that time. In this study, the correlation between light spectrum and intensity data and p11 levels will determine the validity of the "Gray" or "Gloom" Period and if its effect on cadets has a biological basis. The Photonics Research Center has measured ambient light data at different locations on West Point in Cadet Area to correlate the relationship between the light data and depression. The BS&L department enrolled cadet volunteers to take the BDI-II and Zung surveys for depression and consent to have their blood drawn for p11 analysis over the course of a semester. The Center for Molecular Science in the department of Chemistry and Life Science processes the blood samples and conducts blood work to separate the layers of blood into peripheral blood mononuclear cells (PBMCs), Plasma, and red blood cells.

KEYWORDS: p11, depression, seasonal affective disorder, qPCR

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Lattice Boltzmann Model Simulations of Atmospheric Boundary Layer Flows

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As a part of the ABLE (Atmospheric Boundary Layer Environmental) modeling system, a Lattice Boltzmann Model (LBM) prototype was developed recently at the US Army Research Laboratory to simulate the complex turbulent flows in the atmospheric boundary layer. The model can accommodate mechanical and thermal forcing due to buildings and the ground surface, and the drag forces of tree canopies are also included. As initial verification, we used the LBM to simulate turbulent, boundary-layer flows over idealized terrain and urban areas. Two-dimensional examples of thermally driven flows are also used to demonstrate the capability of thermal energy coupling for convective and stably stratified flows. The final demonstration is flow over a forested area.

KEYWORDS: Lattice Boltzmann Model, Atmospheric Turbulence Modeling, Urban Atmospheric Flow Modeling

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Torso Borne Loading Redistribution

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Lower back injuries are one of the leading causes for soldier healthcare visits. In order to combat this USMA, in conjunction with ARL and NSRDEC, are examining various ways to offload the shoulder borne load from a plate carrier system to the soldier's pelvis, bypassing the lower spine. The ATLAS team is current working on the third iteration of this project. The redesign currently includes improvements include a new hip belt focusing on increased comfort, a new adjustability system to allow more customization based off of wearer preference, and finally a new hip anchor that will reduce pressure points while increasing stability and durability. While technology has continued to evolve over the past several decades, the weight that soldiers are required to carry has not. Increasing unit readiness and soldier effectiveness is crucial to the ongoing success of America's Armed Forces.

KEYWORDS: Torso loading, Spine, Redistribution, Soldier performance

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Analysis of Bone Patellar Tendon Bone Graft Fixation for ACL Reconstruction using a Porcine Model

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The Anterior Cruciate Ligament, or ACL, is one of the four ligaments of the knee that allows for proper biomechanical function. The ligament is often damaged and reconstruction is frequently necessary to restore proper function. Better methods in reconstruction can lead to a more optimal recovery. A common method to complete reconstruction is with a Bone Patellar Tendon Bone autograft, or BPTB. The BPTB graft has two different methods of fixation. Research into these two methods could lead to findings of a more optimal way to complete reconstruction. When doing research on these method, a porcine model is often used. The porcine model has been validated for use of research on ACLs through studies done on its ACL dependence. This study used 27 porcine ACL constructs consisting of porcine tibias and porcine BTB grafts. The BTB grafts were cut to lengths of 20 mm, all with a10--mm diameter. Each reconstruction used a 9x25--mm titanium interference screw. 10--mm diameter tunnels were drilled to a standard anatomic tibial insertion site. 13 of the porcine ACLs had the interface screw placed between the tibia and the graft's cancellous bone. The other 14 ACLs had the interface screw placed between the tibia and the graft's soft tissue. Tensile loading was performed with the force applied parallel to the tibial shaft. After cyclic loading, the reconstructions underwent ultimate load--to-failure testing. Ultimate load-to-failure, elongation, stiffness, and peak stress were all recorded. All modes of failure were visually inspected and recorded as tendon failure versus bone block failure. The mean ultimate failure load for the cancellous side was 493 ± 245 N and for the soft tissue side was 304 ± 145 N. 69% of cancellous side specimens survived 1000 cycles of load testing while 21% of soft tissue side specimens survived 1000 cycles of load testing. Failure modes suggest cancellous side interference screw fixation is stronger because of the prevalence of bone plug pullouts and low tendon failures in the soft tissue side group. The findings are not conclusive enough to warrant recommendations for changes in surgical procedure. Further study is necessary to limit variability in tendon size, increase the sample size, and better control tendon thawing and hydration.

KEYWORDS: ACL Reconstruction, Bone Patellar Tendon Bone autograft, cancellous bone, soft tissue
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Persistence homology of evolving collaborative networks

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Persistent homology was proposed as an algebraic tool to study features in data at different scales. The approach requires a sequence of densifying simplicial complexes called a filtration. Through constructing a filtration by varying a threshold parameter, persistent homology has been used recently to study topological signatures in static weighted networks, e.g., scientific collaboration networks, brain networks. We study *time evolving* collaboration networks using time as the varying parameter, thus leading to a *temporal filtration* of simplicial complexes, where each simplicial complex in the filtration represents the collaborations occurring until the indicated time.
The topological properties of interest that arise from this study are the number of holes, which are a measure of cyclicity, and the higher-dimensional voids. In the study, we contrast the growth in the number of holes in the DBLP co-authorship and the IMDB author collaboration datasets over the period of several decades. We observe that the number of cycles in the DBLP dataset grows exponentially with time, while for the IMDB dataset it is almost linear. We also find that the IMDB dataset possesses more higher-dimensional structures or voids. For both datasets, we find that an overwhelmingly large amount of homology (>99% of holes and voids) is found in the largest connected component. These results leads us to conclude that persistent homology could be used as a tool to study and compare evolving collaboration networks. As future work, we intend to propose generative models that could simulate the evolution of collaboration networks.
KEYWORDS: Topological Data Analysis, Persistent Homology, Network Science
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Experiments with a Poppy Humanoid Robot Platform

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The development of a stable walking gait for a Poppy Humanoid robot is presented. Using just the legs of an open-source humanoid robot with 5 degrees of freedom in each leg, stable stationary positions were found with the intent of programming the robot via LabView to move from one stable position to another to achieve a walking motion. A typical human walking gait was not successful with this robot because of the strength of the motors and friction caused by the shoes worn by the robot. A side-to-side rocking motion proved successful in causing forward motion of the robot because it lifted the leg enough to overcome the friction of the shoes. Though a walking motion was achieved, further research is necessary to successfully make the Poppy Humanoid robot capable a walking in a human manner.
KEYWORDS: Humanoid Robot, LabView
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Nanofiber Paper Airplane: Paper Manufacturing for Optimized Flight

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Paper airplanes are limited in their performance by the poor physical qualities of commercially available, cellulose based paper. Specifically, paper airplanes need to be lighter, stiffer, and more hydrophobic than traditional paper to improve their flight capabilities. A new paper formed from cellulose nanofibers enables more efficient, longer flight from paper airplanes. These nanofibers were spun using rotary jet spinning (RJS) and pressed into paper-like mats using an automated mechanical press. Due to its ability to be formed into multiple mold types and the nano-scale fiber diameters, the nanofiber paper created during this project was able to produce near-lotus effect type hydrophobicity. Contact angles approached 150 degrees which, compared to commercially available paper's 108 degree contact angle, offers significant improvements and points to an increased hydrophobicity. Improving on commercially available paper, the nanofiber paper measured 18% less dense. Additionally, the nanofiber paper displayed similar stiffness as commercially available paper. With these qualities, the RJS spun, cellulose based, nanofiber paper offers a more effective alternative to paper airplane construction.
KEYWORDS: Nanofibers, superhydrophobicity, lotus effect, rotary jet spinning
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The Impact of Surface Energy and Surface Morphology on Thrombogenesis in Biomedical Devices

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One of the most common causes of medical device failure is thrombus formation caused by adhesion of plasma proteins and platelets to the medical device surface.1 The subsequent thrombus formation is often treated with anticoagulant drugs. 2 However, the administration of these drugs is not ideal for all patients, and there may be applications where these drugs are not completely e_ective in preventing thrombogenesis. A new medical device surface material design is needed to prevent thrombogenesis without the use of anticoagulant drugs. This study aims to apply the Lotus E_ect (hierarchical micro and nano scale surface features) in order to produce a superhemophobic surface that will have similar self-cleaning properties as the lotus leaf to reduce protien adhesion and thrombogenesis. Additionally, the lotus type surface features will create a smaller apparent surface area for protein binding when the liquid rests in a Cassie-Baxter state. For this study we will use a variety of materials commonly found in implant devices for the construction of our new surface. The apparent surface area - the area of the surface features compared to the total surface area of the material, and the surface energy of the material will be the two major parameters modi_ed in this study. The e_cacy of the new hemophobic material to reduce thrombogenesis will be evaluated by two tests: the sliding angle test between the blood and the new material and by a bicinchonic acid assay measuring the protein adhesion to the surface.3 It is the goal of this study to show that micro and nano scale features, when optimized with the correct surface energy, can be used to create a surface technology applicable to medical implant materials that will help improve the success of medical implant devices.
KEYWORDS: thrombogenesis, superhemophobic, bicinchonic
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A Vertex Cover Algorithm for A Directed Graph

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The problem of determining a minimum vertex cover is NP-hard. In this work, an algorithm to approximate such a cover for a directed graph is presented. The input for the algorithm is the adjacency matrix for a graph, thus, it is applicable to an arbitrary directed graph with the caveat that larger graphs will have a longer run time. For the purpose of visualization, the algorithm is demonstrated on a small set of problems with known solutions. Then, the algorithm is applied to a subset of the tasks in the Army Training Network to approximate the solution to a minimum vertex cover for the purpose of identifying tasks that commanders should prioritize when allocating scarce resources such as time and money. The algorithm contains several important abilities. (1) Users are allowed to specify an arbitrary subset of vertices that must be contained in the vertex cover. In the context of the application of the algorithm considered in this work, this equates to a commander having the ability to specify that certain tasks must be completed regardless of whether or not they would be selected in the optimal vertex cover. (2) Users are allowed to assign weights/costs to each vertex. In the context of the Army Training Network, this equates to having the ability to specify the time or monetary cost associated with selecting a task to be completed. Advantages and disadvantages of this algorithm compared to other vertex covering algorithms are discussed.
KEYWORDS: Graph theory, vertex cover, maximum independent sets, and algorithm
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Bio-Templated Nano-wire Films for Lightweight Multi-functional Materials

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Biological hydrogels can serve as 3-dimensional bio-templates for tunable nano-porous materials that serve both as electrochemically active high surface area and structural material. We present a general approach to 1) form a biological hydrogel; 2) sensitize the hydrogel bio-template using catalytic palladium ions to mediate the electroless deposition; and 3) synthesize metallic 3-dimensional networks of nano-wire films via electroless deposition. Such multi-functional electro-mechanical materials are envisioned to enable a broad range of Army platforms and serve as a nano-architecture for applications such as photovoltaics, catalytic systems, fuel cells, sensors, and energy absorption.
KEYWORDS: Hydrogel, bio-templates, nano-materials, electrochemical, biotemplating, fuel cells
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On Demand Manufacturing of Reclaimed and Indigenous Materials

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United States Army warfighters in theater are often faced with the challenge of broken, damaged, or missing parts necessary to maintain the safety and productivity required. These parts are often difficult to come by, especially at remote forward operating bases that have little regular contact with the supply chain. This leads to either rough repairs, which have the potential to be dangerous, or long time delays, which can lose the Army money and tactical positioning.
One solution, which is explored in this project, is to give warfighters the capability to manufacture the parts required on site. Indigenous materials such as metal scrap and waste plastics can be utilized to improve the self-reliance of warfighters on forward operating bases by cutting costs and decreasing the demand for the frequent resupplying of parts by the supply chain. It would also allow for parts to be made in a time-effective matter and in a way that would allow for post-production modifications. Experimentation is conducted to turn waste plastics into polymer pellets that can be heated and extruded into filament. The filament can then be used for additive manufacturing methods like 3D printing, which allows for the capability of designing and building virtually any plastic part. These could either be utilized as-produced or be used, along with existing and functional parts, to create molds for casting. Scrap metal can be melted and poured into metal or greensand molds using basic foundry techniques to create an exact replica of a part or to create a uniform metal block that can be machined with a small, portable subtractive manufacturing device like a CNC mill. Samples made using all of the explained methods will be tested for strength and feasibility.

KEYWORDS: additive manufacturing, indigenous manufacturing, scrap metal, recycled plastics, metal casting, 3D printing, filaments

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Theoretical studies of imidazole binding to an iron (001) surface

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Organic inhibitors are used throughout various industries to help reduce metallic corrosion. Computational tools can be used to design new organic inhibitors as well as help to elucidate the inhibition mechanism. To determine the most accurate and computationally efficient way to carry out these studies, it is important to assess the validity of several underlying assumptions. A popular method for determining corrosion inhibition efficiency from quantum mechanical calculations is through the calculation of the organic inhibitors binding energy to the metal surface. This can be done by calculating the HOMO-LUMO gap of the organic inhibitor and approximating the binding, or by calculating the binding energy directly using a cluster or slab model to represent the metal. These calculations almost exclusively use density functional theory (DFT). Here, we compare DFT to several higher level methods, including the Random Phase Approximation (RPA) and Diffusion Monte Carlo (DMC) for cluster and slab models.

KEYWORDS: Corrosion, Density Functional Theory, Diffusion Monte Carlo

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Understanding the Effect of Amino Acid Conformation on Binding Affinity to Au(111) Using Quantum Mechanical Calculations

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Designing peptides with controllable binding to inorganic surfaces necessitates understanding the binding interactions between individual amino acids and the surface. To date, quantum mechanical (QM) calculations have provided insight into the relative binding affinities of residues on various inorganic surfaces such as gold. However, owing to limited computational resources, these studies are often performed with periodic models where care must be taken to understand the effects of model size and periodicity, as well as any possible additional limitations in the method. For instance, in many cases only a single conformation of the amino acid on the surface is studied. This study aims to improve our understanding of relative binding affinities of amino acids on Au(111) by using QM calculations to determine the interaction energies of various amino acids on an Au(111) slab of sufficient size to mitigate possible artifacts induced by periodicity. In addition, a number of orientations of the residues on the surface will be studied to compare the effect of residue conformation on binding affinity. The results will be discussed in the context of existing computational and experimental data for the binding of amino acids on Au(111), as well as the potential for using this data to refine existing bio-inorganic force fields (FFs) and guide future molecular dynamics (MD) studies of gold binding peptides (GBPs).

KEYWORDS: Inorganic, Periodicity, Peptides

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Development of a predictive model from a simulated artificial clostridium fermentation towards real-time culture monitoring

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In previous work, Raman spectroscopy together with statistical modeling was shown to be effective for real-time data acquisition of consumable sugar (glucose) and accumulating products (butyric acid, acetic acid, and butanol) in a clostridial fermentation culture. Developed partial-least squares (PLS) models were applied to both agitated and static cultures with the former showing preferred modeling parameter values (R2Y = 0.99 and Q2Y = 0.98). Model outputs were shown to be comparable to off-line analyzed data from traditional HPLC for new clostridial experimental data through cross-validation. In this study, a bottom-up approach is employed where experimental data from HPLC analyzed data for reaction components is used to simulate an artificial fermentation culture devoid of cell activity. Raman spectra of corresponding reaction components; (i) glucose, (ii) butyric acid, (iii) acetic acid, and (iv) butanol, in specified proportions were acquired for corresponding time points. The acquired spectra together with known concentrations of reaction components were used to build new sets of PLS models. These new models will be compared with original models created for the actual clostridial fermentation for model performance with both sets of models executed in real-time.

KEYWORDS: Raman spectroscopy, chemometrics, MVDA, predictive modeling, clostridium, fermentation, real-time monitoring, bottom-up approach

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An Unsteady Two-Dimensional Complex Variable Boundary Element Method

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The Complex Variable Boundary Element Method (CVBEM) is extended to applications in modeling time-dependent potential problems governed by the Laplace equation. Typically, CVBEM applications have been limited to approximating solutions to steady-state problems, however, by coupling a CVBEM-type approximation series with a generalized Fourier series, unsteady transport problems can be modeled. The modeling procedures presented can be applied to approximate the solution to any boundary value problem governed by the Laplace equation, however, the specific application considered in this work is a problem related to modeling unsteady heat transport. The underpinning of the new technique is to decompose the global problem into two sub-problems; namely, a transient and a steady-state sub-problem. The sum of the Fourier series solution to the transient component of the problem and the CVBEM series solution to the steady-state component of the problem is the solution to the global boundary value problem. The mechanics and solution success of this new technique are demonstrated and discussed.

KEYWORDS: Complex Variable Boundary Element Method (CVBEM), Laplace equation, time-dependent, numerical solutions to partial differential equations, potential problems, flow nets

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