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2021 DEVCOM Army Research Laboratory Summer Student Program, Volume II: Compendium of Abstracts

Compiled by Danell Diggs

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2021 DEVCOM Army Research Laboratory Summer Student Program, Volume II: Compendium of Abstracts

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*Outreach Office, Plans and Programs, Laboratory Operations,
DEVCOM Army Research Laboratory*

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14. ABSTRACT The US Army Combat Capabilities Development Command Army Research Laboratory Summer Student Symposium is a DEVCOM Army Research Laboratory Director's Award Program for all the students participating in various summer scholarship and contract activities across DEVCOM ARL. The goal of the program is to recognize and publicize exceptional achievements made by the students and their mentors in support of Army science. All college undergraduate and graduate students receiving research appointments and conducting summer studies at DEVCOM ARL are automatically enrolled in the symposium program. As an integral part of their summer study, all students are required to give a presentation summarizing their major activity and its end product. The program is conducted on two separate competitive levels: undergraduate and graduate. While technical presentations followed the same format, the evaluation considered the difference in academic level. All students presented their work orally and directorate judging panels selected two technical presentations from each competition category for the annual laboratory-wide competition at the Summer Student Symposium, held on 12 August 2021. At the symposium, the students presented their technical presentations to the DEVCOM ARL Director and an ARL Fellows panel. This volume contains many of the abstracts for the technical presentations prepared for FY21.					
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Director's Foreword

The US Army Combat Capabilities Development Command Army Research Laboratory mission is to “provide innovative science, technology, and analyses to enable full spectrum operations.” As the Army’s corporate laboratory, we provide the technological underpinnings critical to providing capabilities required by our current and future Soldiers.

Our nation is projected to experience a shortage of scientists and engineers. DEVCOM Army Research Laboratory recognizes the criticality of intellectual capital in generating capabilities for the Army. As the Army’s corporate laboratory, addressing the projected shortfall is a key responsibility for us. We have, therefore, identified the nation’s next generation of scientists and engineers as a key community of interest, and have generated a robust educational outreach program to strengthen and support them. We have achieved many successes with this community. We believe that the breadth and depth of our outreach programs will have a significant positive effect on the participants, facilitating their journey toward becoming this nation’s next generation of scientists and engineers.

A fundamental component of our outreach program is to provide students research experiences at DEVCOM ARL. During the summer, we supported research experiences at DEVCOM ARL for over 300 undergraduate and graduate students. Each of these students writes a paper describing the results of the work they performed while at DEVCOM ARL. All of the technical presentations were of high quality, but only a few could be presented at our student symposium. Many of the abstracts for the technical presentations prepared this summer are contained in this volume of the proceedings, and they indicate that there were many excellent research projects with outstanding results. It is unfortunate that there was not enough time for us to have all of the technical presentations presented. We would have enjoyed hearing them all.

We are very pleased to have hosted this outstanding group of students for the summer. It is our hope that they will continue their pursuit of technical degrees and will someday assist us in providing critical technologies for our Soldiers.

Patrick Baker
Director

1. Introduction

The US Army Combat Capabilities Development Command Army Research Laboratory Summer Student Symposium is a DEVCOM Army Research Laboratory Director's Award Program for all the students participating in various summer scholarship and contract activities across DEVCOM ARL. The goal of the program is to recognize and publicize exceptional achievements made by the students and their mentors in the support of Army science.

All college undergraduate and graduate students receiving research appointments and conducting summer studies at DEVCOM ARL are automatically enrolled in the symposium program. As an integral part of their summer study, all students are expected present an oral presentation on their work, which summarizes their major activity and its end product.

The program is conducted on two separate competitive levels: undergraduate and graduate. The format of the paper in both levels is the same. However, the evaluation will take into consideration the difference in the academic level of the students.

All students present orally during a directorate review. Directorate judging panels selected one or two technical presentations from each competition category for the annual laboratory-wide competition at the Summer Student Symposium, held on 12 August 2021.

At the symposium, the students presented their technical presentations to an audience of DEVCOM ARL scientists and engineers, including the DEVCOM ARL Director and a DEVCOM ARL Fellows panel.

This volume of the Summer Student Symposium Proceedings contains many of the abstracts for the technical presentations prepared for the Summer Student Symposium Program for FY2021.

2. FY2021 Student Abstracts

Accelerated User Reasoning for Operations, Research, and Analysis (AURORA) Platform Static Vulnerability Testing

Clinton Anderson

Project AURORA (Accelerated User Reasoning for Operations, Research, and Analysis), being developed at DEVCOM ARL, uses mixed reality to overlay computerized images on real-world displays, providing real-time information combined with useful amplifying visual displays such as numbers, groupings, and target information. The collaboration of mixed reality with standard methods of intelligence has led to several strides in advancing effectiveness in communication among Soldiers on the battlefield, organization among leaders, and transfer of information through a squad leader. This increased information flow seeks to improve simulated training, enhance command and control, and improve the lethality of warfighters on the battlefield.¹ To protect this valuable data, a black box software testing technique called “fuzzing” can be used to find bugs in an application before deployment by injecting various data in an automated fashion.² This research covers several free fuzzing tools such as Peach and WinAFL, as well as commercial tools such as GitLab’s DevSecOps and Beyond Security’s BeSECURE, while exploring how software such as the National Security Agency’s reverse engineering tool Ghidra, virtual environments, and various operating systems and integrated development environments all work in conjunction to create a secure fuzzing platform.

I wish to acknowledge the mentorship of Dr Mark Dennison, XR Projects Lead; Mr Theron Trout, Senior Software Engineer; Dr Nathan Hahn, Computer Scientist; and Ms Tiffany Raber, Research Psychologist.

¹ARL Public Affairs. Army researchers explore benefits of immersive technology for Soldiers. [www.army.mil](https://www.army.mil/article/216131/); 2019 Jan 16 [accessed 2021 July 26]. <https://www.army.mil/article/216131/>.

²Fuzzing. OWASP; 2021 [accessed 2021 July 26]. <https://owasp.org/www-community/Fuzzing>.

Atomistic Study of Phase-Dependent Structural and Electronic Properties of Molybdenum Trioxide (MoO₃)

Harsha Antony

Transition metal oxides (TMOs) are widely used in electronic and optical applications due to their interesting crystal phase-dependent structural and electronic properties. The goal of this study is to research the structural and electronic properties of bulk and slab structures of molybdenum trioxide (MoO₃). Using a multiscale approach, including classical molecular dynamics (MD) and first principle calculations, the amorphous MoO₃/diamond heterostructure is designed. This heterostructure will be used to study surface charge transfer between the diamond and TMO layer. Prior to the amorphous model design, we have performed thickness calibration of the crystal MoO₃ system using a first principle method. Based on the binding energy and work function analysis, we have found that the (010) slab, with the thickness of three-unit cells, represented a bulk system. Furthermore, due to the lack of a potential force field required for the MD simulation, we have calibrated a few simple potential force fields designed for a crystal system to produce amorphous models and compared radial distribution functions against the available experimental data. Though preliminary results are encouraging, further analysis is warranted to garner confidence on the generated amorphous MoO₃ and MoO₃/diamond heterostructure for charge transfer study.

I wish to acknowledge the mentorship of Dr Mahesh Neupane, DEVCOM ARL, and Dr Alex Greaney and Pegah Mirabedini, Computational Materials Science Lab, University of California.

Approximate Persistent Exploration in Reinforcement Learning over Continuous Spaces

Amrit Singh Bedi

Reinforcement learning is a framework for interactive decision-making with incentives sequentially revealed across time without a system dynamics model. Due to its scaling to continuous spaces, we focus on policy search where one iteratively improves a parameterized policy with stochastic policy gradient (PG) updates. In tabular Markov decision problems, under persistent exploration and suitable parameterization, global optimality may be obtained. By contrast, in continuous space, the non-convexity poses a pathological challenge as evidenced by existing convergence results being mostly limited to stationarity or arbitrary local extrema. To close this gap, we step toward persistent exploration in continuous space through policy parameterizations defined by distributions of heavier tails defined by tail-index parameter α , which increases the likelihood of jumping in state space. Doing so invalidates smoothness conditions of the score function common to PG. Thus, we establish how the convergence rate to stationarity depends on the policy's tail index α , a Hölder continuity parameter, integrability conditions, and an exploration tolerance parameter introduced here for the first time. Further, we characterize the dependence of the set of local maxima on the tail index through transition time analysis of a suitably defined Markov chain, identifying that policies associated with Lévy processes of a heavier tail converge to wider peaks. This phenomenon yields improved stability to perturbations in supervised learning, which we corroborate also manifests in improved performance of policy search, especially when myopic and farsighted incentives are misaligned.

I wish to acknowledge the mentorship of Alec Koppel.

Retrosynthesis of Benzoquinoline Derivative Ligands for Cyclometalated Iridium Complexes

Evan Bolster

Cyclometalating iridium (III) complexes containing acetylacetonate and two fairly conjugated ligands, such as 2-phenylpyridine, exhibit a strong, temporary absorption of visible light following photoexcitation. This process is called reverse saturable absorption (RSA) and is currently investigated by DEVCOM ARL. Cyclometalated iridium complexes typically exhibit excited state lifetimes on the order of hundreds of nanoseconds to microseconds before returning to the ground state. Our goal is to improve the photophysics of these complexes by designing materials with excited state lifetimes on the order of hundreds of microseconds to milliseconds. These types of materials would be advantageous for RSA applications and more generically for photocatalysis and organic light-emitting diodes. Commonly, extending aromatic conjugation or manipulation of electron donating or electron withdrawing functional groups is investigated as a way to enhance excited state lifetimes. This research identified and performed a retrosynthetic analysis of four different benzoquinoline-based ligands that had potential to improve the excited state. All four of these compounds would employ Suzuki-Coupling reactions to create carbon-carbon bonds between a pyridine and a phenyl ring. Two molecules would then use a Sonogashira coupling reaction to create a terminal alkyne on the 2-carbon of the pyridine or phenyl. The other two molecules would create the alkyne from an aldehyde using a Bestmann-Ohira reaction. Finally, all four molecules would be treated with triflic acid to induce cycloisomerization and the formation of the benzoquinoline ring. It is predicted that extending the conjugation of these ligands and enhancing their rigidity, especially between the iridium-bonded carbon and nitrogen, should dramatically increase the duration of the complex's excited state. Additionally, ligand positions for further derivatization with electron donating or electron withdrawing functional groups were identified.

I wish to acknowledge the mentorship of Dr Ryan M O'Donnell and Dr Thomas N Rohrabach Jr, DEVCOM ARL-SEDD, for their mentorship. I also acknowledge funding from the US Army Cadet Command that supported my ROTC summer internship.

Can't We Just Agree With the HAT? Agreeableness in Human-Agent Teaming

Giovanna Camacho

Part of the DOD's modernization initiative is the Next Generation Combat Vehicle program. This program specifically focuses on requirements such as being optionally manned, operating remotely, and utilizing artificial intelligence with certain tasks to assist crewmembers. Part of being successful in this initiative is recognizing both where the Human-Autonomy Teaming (HAT) falls short and what actions can be taken to enhance their effectiveness. Recent advancements in artificial intelligence and machine learning have enabled the creation of learning capable agents (LCAs). Understanding how the operators' personality can influence their performance outcomes in HATs can be helpful in the development of autonomy that better supports their human teammate. Individuals who are high in agreeableness are helpful, optimistic, get along well with others, and develop strong relationships with teammates. As such, individuals high in agreeableness can be expected to perform well in HATs. All participants in this study scored above average on the Agreeableness measure (>3 out of 5), so we examined how subtle differences in agreeableness affect task outcomes.

This 2 (reasoning transparency; opaque vs. transparent) $\times$ 3 (learning transparency; implicit, explicit, human-directed) fractional factorial within-subjects study assesses the effects of transparency of agent learning on a threat classification task. Agreeableness, as a personality trait, can be a desirable trait in any team member, and from these results, it appears the same holds true for persons in HATs that include LCAs. While there are slight benefits for performance outcomes and teaming attitudes due to increased transparency, higher agreeableness seemed to temper the added difficulty of instructing the agent. Further research could examine ways to support individuals' innate agreeableness when teaming with LCAs.

I wish to acknowledge the mentorship of Dr Julia Wright, Dr Albert Boquet, Dr Andrea Krausman, Dr Patrice D Collins, Ms Jamie Wilson, Mr Joseph Alexander, Ms Johanna Garcia, and DEVCOM ARL for allowing me the opportunity and providing support needed during this internship.

Catalytic Nanothermometers: New Temperature Model in Theory and Practice

Alison Carroll

Photocatalysis is a growing field of research within the scientific community due to its intriguing use of heat production in materials using light, which could be an asset to the Army's chemical needs.

Much research has been done exploring the relationship between thermal and optical properties of nanoscale materials, most notably gold, yet there is a gap in understanding between theoretical and experimental results. This research project aims to assist researchers in better understanding this relationship using nanothermometers made of DNA and gold. This will allow additional photocatalysts of interest, transition metal nitrides like titanium nitride, to be explored with a new temperature model. Optical properties observed in the lab will be compared to those seen using Discrete Dipole Scattering (DDSCAT), a dipole approximation program. From here, the nanothermometers will be examined when heated using fluorescent signaling, and an absorbance/temperature model can be proposed. This new model could offer an improved, more cost-efficient, comprehensive photocatalytic process for the Army.

I wish to acknowledge the mentorship of Dave Baker.

Characterization and Tracking of Wing-Tip Vortex Signatures in Doppler Light Detecting and Ranging (LIDAR) Data Using Cluster Analysis

Jana Catuche

Large aircraft in flight can generate two counter-rotating vortices—one off the tip of each wing—that pose a potential hazard for nearby aircraft and paratroopers. Army researchers have used a Doppler light detecting and ranging (LIDAR) system to measure radial velocity signatures of wing-tip vortices produced by a series of C17 test flights. The objective of this research is to enhance algorithms implemented in MATLAB software to improve automation of wing-tip vortex detection, isolation, and characterization. Using these tools, I analyze the temporal evolution of the wing-tip vortices produced by the aircraft as they propagate through the atmosphere. Our method combines two unsupervised machine learning approaches: Density-Based Spatial Clustering of Applications with Noise (DBSCAN) and K-means Cluster Analysis. We use DBSCAN to isolate the vortex region from the atmospheric background and other features present in the local wind field. Then, we apply K-means clustering to the isolated vortex cluster region to break it up into different clusters that each represent an aspect of the vortex rotation. We estimate vortex strength from the mean radial wind speed values for each cluster.

I wish to acknowledge Dr David Ligon, Dr Sandra Collier, Mr Melvin Felton, and Dr Max Denis for mentoring and advising me in this project.

Varying Landscapes in Self-Righting Robotics

Pascal Conroy

Current robotic platforms have limited capacity for fall recovery in nonflat terrain. A more robust and flexible system of self-righting is essential to engineering practical unmanned ground vehicles. Development and testing of simulated robotic platforms on landscapes of varying geometry is the first step towards improved self-righting systems. This project attempts to accomplish this step within the DEVCOM ARL Long-range Intramural Mobility and Manipulation Basic Science (LIMMBS) laboratory's self-righting simulation framework.

I wish to acknowledge the mentorship of Mr Matt Kaplan and Dr Chad Kessens for their aid in my research.

Modeling Long-Time Shock Wave Propagation Using a Moving Window Concurrent Atomistic-Continuum (CAC) Framework

Alexander Davis

Atomistic methods have successfully modeled different aspects of shock wave propagation in materials over the past several decades, but they suffer from limitations that restrict the total runtime and system size. Multiscale methods have been able to increase the length and time scales that can be modeled, but employing such schemes to simulate wave propagation and evolution through engineering-scale domains is an active area of research. In this work, we use the Concurrent Atomistic-Continuum (CAC) method to model shock wave propagation through a one-dimensional monatomic chain. The shock is characterized using third-order nonlinear Eulerian thermoelastic theory, and we develop two distinct moving window techniques to track the shock front for long simulation times. In the first method, the entire domain follows the shock in a conveyor fashion, while in the second method, the fine-scaled region travels through the chain by the simultaneous coarsening and refinement of the continuum regions. The CAC domain and moving window methods are verified through dispersion relation studies and phonon wave packet tests. We achieve good agreement between the simulated shock velocities and the values obtained from theory with the conveyor technique, while the coarsen-refine technique allows us to follow the propagating wave front through the entire domain. This work showcases the ability of the CAC method to accurately simulate propagating shocks and also demonstrates how a moving window technique can be used in a multiscale framework to study highly nonlinear, transient phenomena.

I wish to acknowledge the mentorship of Dr Jeffrey Lloyd for being so patient with me and taking a real interest in my research.

Additionally, I would like to thank Dr John Clayton for providing valuable feedback during the development of this framework. Finally, I would like to thank my PhD advisor, Dr Vinamra Agrawal, for his passion for engaging students in their research.

Improving a Semantic Hierarchy Ontology by Resolving Homonyms

Seth Ellis

The Scene Understanding (SUN)¹ Database has thousands of images, each coupled with an annotation file that defines the bounding box of objects and labels that best describe that object. These labels assigned to objects at times can have several lexical definitions differing in meaning, parts of speech, and/or pronunciations, making discerning their definition difficult without context. Across multiple labels were examples of the same word being used to describe differing objects. This can make assigning a correct hierarchy to a given label name tricky and impair performance of object recognition models. To resolve this discrepancy in labeling, two visual tools programmed in Python were made. The first inspected a given label to identify if the label name was an instance of a homonym, and the second renamed the label associated with the object. If renaming was necessary, the WordNet² application programming interface was used to find a suitable and more accurate replacement label for the object. A handful of homonyms were found, and by resolving them, consistency between object labels and image appearance was improved. It will possibly improve a model's training when tested on the data set. Autonomous vehicles can also make use of this hierarchical knowledge to improve recognition of objects in addition to using knowledge to prioritize and relay necessary information.

I wish to acknowledge the mentorship of Dr Andre V Harrison, Eric Wilt, and Darius Jefferson II.

¹Xiao J, Hays J, Ehinger K, Oliva A, Torralba A. SUN database: large-scale scene recognition from abbey to zoo. Proceedings of the IEEE Computer Society Conference on Computer Vision and Pattern Recognition; 2010. <https://groups.csail.mit.edu/vision/SUN/hierarchy.html>.

²Fellbaum C. WordNet: an electronic lexical database. MIT Press; 1998. <https://wordnet.princeton.edu/>.

Anion Intercalation for Actuation Applications

Luke Hakun

Anion intercalation in graphite is a field of research that has uses for both energy storage and actuation. Anion intercalation occurs when electrons are removed from the graphite under electrochemical oxidation and anions from the electrolyte intercalate between graphene sheets for charge compensation. Common anions are Hexafluorophosphate (PF_6^-), bistriflimide (TFSI^-), and bis(fluorosulfonyl)imide (FSI^-). The degree of intercalation is classified via stages, where a stage refers to how many layers of graphene are between each anion intercalated layer. Figure 1, taken from Schmuelling et al.¹, gives a visual representation of staging.

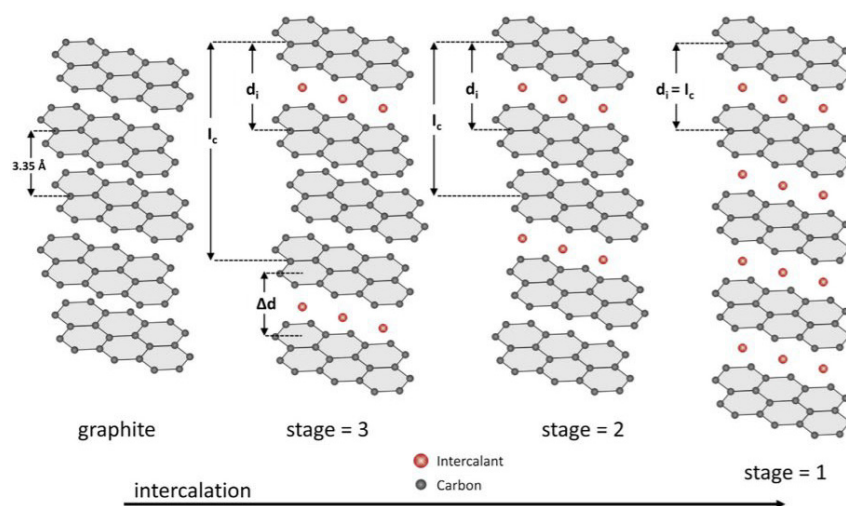


Fig. 1 Staging

By using a specialized form of graphite—highly oriented pyrolytic graphite, where all the graphite layers are oriented in the same direction in a macroscopic crystal measuring 1–2 cm on a side—the increase in crystal thickness as anions intercalate can be measured in real time under different loads. As the graphite intercalates and the reaction progresses, the intercalated anions increase the height of the graphite leading to large expansion in the c-axis direction, perpendicular to the graphene planes. This change in crystal thickness is used to facilitate reversible mechanical actuation. The ability to actuate against a force has been measured for various loads.

I wish to acknowledge the mentorship of Dr Jeff Read for offering me this opportunity and teaching me the way around the lab.

¹Schmuelling G, Placke T, Klopech R, Fromm O, Meyer H-W, Passerini S, Winter M. X-ray diffraction studies of the electrochemical intercalation of bis(trifluoromethanesulfonyl)imide anions into graphite for dual-ion cells. *J Power Sources*. 2013;239:563–571. ISSN 0378-7753; <https://doi.org/10.1016/j.jpowsour.2013.03.064>.

A Multiphase Continuum Mechanical Model of the Lung Parenchyma

Zachariah Irwin

The mechanisms of lung injury have been studied since World War I when Soldiers were initially thought to have been exposed to noxious gases or suffered severe trauma to their nervous system.¹ By World War II, it became clear that shockwave-induced deformations (e.g., from local detonations) of smaller lung tissue (lung parenchyma) were responsible for larger-scale injuries, such as hemorrhage, long-term diseases, such as pneumonia, and in many cases, immediate death.^{2,3,4} The progression of damage—specifically the biological processes that govern the pathology and eventual healing—and mitigation of damage through personal protective equipment, are of key interest to the Army and is an active area of research.

Four distinct phenomena contribute to pulmonary contusion: spalling effects, inertial effects, implosion, and tearing of the alveoli.³ Current research at DEVCOM ARL addresses the latter two, assuming a single-phase finite strain continuum constitutive model implemented within a finite-element model of an alveolar air sac and the entire lung itself, wherein the trapped pore air is assumed to move with the solid tissue.^{5,6} Our project aims to connect these two continuum scales via an intermediate scale model of the lung parenchyma, which, in contrast to the two other models, uses the theory of porous media to account for direct interactions between both phases, namely the pore air and solid tissue. We demonstrate the effects of a separate fluid phase on lung parenchyma as it is deformed by a shock wave. Most notable is the effect the pore air pressure has on the total lung parenchyma pressure, a metric that cannot be determined from a single-phase model. Future work will address temperature contributions to the predicted response and multiscale linking among lung alveoli, lung parenchyma, and full lung models using sophisticated machine-learning techniques to reduce computational cost of resolving alveolar deformation.

I wish to acknowledge the mentorship of Dr Clayton and Prof Regueiro. I thank Dr Bobby Doney for granting computing hours on the Terminal Weapons Effects project for DOD High-Performance Computing systems.

¹Hooker DR. Physiological effects of air concussion. *Am J Physiol.* 1924;67:219–274.

²Burford TH, Burbank B. Traumatic wet lung. Observations on certain physiologic fundamentals of thoracic trauma. *J Thorac Surg.* 1945;14:415–424.

³Cohn SM, DuBose JJ. Pulmonary contusion: an update on recent advances in clinical management. *World J Surg.* 2010 Aug 1;34(8):1959–70.

⁴Maynard RL, Cooper GJ, Scott R. Mechanisms of injury: bomb blast injuries and explosions. In: *Trauma*, Westaby S, editor. Heinemann; 1989.

⁵Clayton JD, Freed AD. A continuum mechanical model of the lung. Army Research Laboratory; 2019. Report No.: ARL-TR-8859.

⁶Freed AD, Zamani S, Paul S, Clayton JD. A dodecahedral model for alveoli. part I. Theory and numerical methods. DEVCOM Army Research Laboratory; 2021. Report No.: ARL-TR-9148.

Measuring Thickness of III-Nitride Semiconductor Films Grown for Optoelectronic Devices

Lesly Henriquez-Saravia

III-Nitride materials are important for compact, efficient, and smaller semiconductor lasers that will help enable quantum information and sensor technology. These devices are made by growing thin layers of different materials on top of a substrate—in this case, using molecular beam epitaxy (MBE). This study focused on modeling reflection properties of wide bandgap semiconductor thin films to determine their thickness and understand MBE growth rates. The films studied consist of cubic-aluminum nitride (AlN) and cubic-gallium nitride (GaN) on top of 3C-silicon carbide (SiC) substrates. The thickness was estimated by comparing the number of oscillations between a model of reflectivity and the collected data. We found that plotting the data as a function of energy instead of wavelength made comparing the oscillations more precise. Although the model did not include absorption at the shorter wavelengths, we could estimate the thickness accurately. We estimated the thickness of the 3C-SiC substrate to be 3284 nm with an error of ± 162 nm. We began modeling reflection for the cubic-AlN and the cubic-GaN layer on top of the 3C-SiC substrate and plan to use the same method to determine their thickness. We plan to refine the model by considering the effect of other factors, such as non-normal light incidence.

I wish to acknowledge DEVCOM ARL for allowing me to participate in their research fellowship. I would also like to thank my mentor, Dr Gregory Garrett, for guidance during this research.

Human–Robot Dialogue Learning

Benjamin Kane

Intelligent robots operating in situated environments with Soldiers will often encounter unfamiliar concepts, such as objects, locations, and actions. For successful interactions, robots need to be able to learn these concepts as they relate to the physical world. One method of learning is through dialogue with humans, where the robot asks questions about its perceptions and learns from answers. The Laboratory University Collaboration Initiative (LUCI) project, led by Drs Matthew Marge and Felix Gervits, aims to create an approach that does not rely on extensive training data. The approach uses a decision network model to automatically generate questions about observable properties of the environment and interpret responses for learning. To evaluate this model in a practical setting, I integrated the model into the Distributed Integrated Affect Reflection Cognition (DIARC) robot architecture and a Unity 3D simulation environment. I implemented the robot actions and natural language capabilities necessary for a proof-of-concept demonstration in which a simulated robot performs a tool organization task that involves the learning of novel concepts. This demonstration shows that this approach to robot question generation is effective for dialogue-based learning in unexplored environments.

I wish to acknowledge the mentorship of Drs Matthew Marge and Felix Gervits. This research was sponsored by the Basic Research Office of the US Department of Defense with a Laboratory University Collaboration Initiative Fellowship.

Field Testing of Bayesian Multimodal Fusion Algorithms for Aerial Tracking of Ground Targets

Ramya Kanlapuli Rajasekaran

Small unmanned aircraft systems (sUAS) show great potential for localization and tracking of radio frequency (RF)-emitting devices in high-threat environments. In such environments, communications are often severely compromised, necessitating an autonomous tracking solution. Complementary sensors, such as vision and RF, help address the shortcomings that arise from relying on a single sensor for tracking in complex surroundings. For these experiments, perception is performed using information received from an RF antenna and a monocular camera, mounted on the sUAS. This work consists of flight testing and refinement of a multimodal Bayesian fusion estimation architecture to solve the problem of continuous, real-time, onboard autonomous tracking of ground targets using sUAS. This model incorporates a number of advancements, which include the design of a region-based RF sensor model¹ and an integrated data association vision sensor model to process the respective measurements. A particle-based Bayesian fusion estimation algorithm² is used to fuse these sensor model outputs to generate a final estimate of target state. Flight tests at DEVCOM ARL will generate the necessary data for verification of estimator performance and inform any adjustments to the algorithm. Further testing will use online estimator outputs for closed-loop control for autonomous target tracking.

I wish to acknowledge the mentorship of Dr Eric Frew, University of Colorado Boulder; Dr Nisar Ahmed, University of Colorado Boulder; and Joseph Conroy, DEVCOM ARL.

¹Kanlapuli Rajasekaran R, Frew E. Assessing particle filter algorithms for tracking radio emitters using small unmanned aircraft. AIAA SciTech: Sensor Fusion and Information Systems; 2019.

²Kanlapuli Rajasekaran R, Ahmed N, Frew E. Bayesian fusion of unlabeled vision and RF data for aerial tracking of ground targets. International Conference on Intelligent Robots and Systems (IROS); 2020 Oct.

Combining Model Agnostic Meta-Learning (MAML) and Langevin Dynamics to Quickly and Accurately Adapt to New Tasks

Christine Kwon

We generally learn and apply knowledge through our past experiences; hence we create artificial agents that emulate this learning process. Meta-learning enhances this process, allowing these artificial agents to learn and adapt from only a small amount of data and prior experience, further accommodating to newly available data. In essence, the goal of meta-learning is for a model, pretrained on a number of different tasks, to efficiently learn and adapt to a new task given a relatively small amount of data.¹ A significant and commonly used meta-learning algorithm is the Model Agnostic Meta-Learning (MAML) algorithm, which trains a model to rapidly adapt to new tasks given a few-shot learning problem. The MAML algorithm trains the model's initial parameters through a few steps of gradient descent to achieve fast learning on a new available task. However, learning and adapting to a new task given only a small amount of data may intrinsically result in substantial amounts of uncertainty, specifically parameter uncertainty.² Consequently, we introduce the inclusion of Langevin dynamics, a class of Markov chain Monte Carlo techniques, which takes the Bayesian approach to capture parameter uncertainty.³ This approach also updates the model's parameters through steps of gradient descent, but it infuses Gaussian noise in its algorithm to take parameter uncertainty into account.³ The combination of the MAML algorithm's ability to quickly adapt to a new task and Langevin dynamics' inclusion of parameter uncertainty will aid us in creating a more robust meta-learning algorithm.

I wish to acknowledge the mentorship of Jemin George for giving me the opportunity to participate in such novel and intriguing research and for guiding me throughout this research experience.

¹ Finn C, Abbeel P, Levin S. Model-agnostic meta-learning for fast adaptation of deep networks. International Conference on Machine Learning (ICML); 2017.

² Kim T, Yoon J, Dia O, Kim S, Bengio Y, Ahn S. Bayesian model-agnostic meta-learning. Neural Information Processing Systems (NIPS); 2018.

³ Welling M, Teh Yee W. Bayesian learning via stochastic gradient Langevin dynamics. International Conference on Machine Learning (ICML); 2011.

Synthesis of Niobate Anodes for Fast-Charge Batteries and Synthesis of Spinel Materials for All Solid-State Batteries

Catherine Lewis

Anodes made using TiNb_2O_7 (TNO) and $\text{PNb}_9\text{O}_{25}$ (PNO) have shown remarkable performance in fast-charge lithium (Li)-ion batteries for their high energy density, fast charging, enhanced safety, and long life cycle, making them viable candidates to evaluate performance and scalability in an Army-relevant environment. Viability needed to be verified for Army applications by scaling the two syntheses and evaluating purity, ease of synthesis, and electrochemical properties. PNO and TNO material was scaled to 100-g batches and synthesized easily through solid-state methods using ammonium dihydrogen phosphate and niobium (V) oxide precursors for PNO and titanium (IV) oxide and niobium (V) oxide precursors for TNO. Further, the TNO was scaled to 400 g using an industrially scalable attritor mill. The batches produced showed high purity and were easily scalable for military applications. The electrochemical studies showed that TNO had an average of 181 mAh/g per cycle and PNO had an average of 236 mAh/g per cycle. This leads to the conclusion that PNO had the best performance because it was able to achieve a higher average capacity per cycle.

All solid-state batteries have been of peak interest since the discovery of fast Li-ion conduction in the cubic garnet structure. The advantages of this battery are higher stability and safety, but there can be issues of slow kinetics due to poor solid–solid contact at phase interfaces. Previously, Li-stuffed spinel structures were studied, and it was found that fast Li^+ ion conduction can be achieved. Since spinels are known electrode materials, enabling fast Li-ion conduction in this structure can enable better kinetics; this is due to a single spinel phase that can be prepared, reducing the amount of solid–solid interfaces. The spinel structures of focus were LATO or LCTO, which were prepared through solid-state methods. To continue the work of this study, these Li-stuffed spinel structures were synthesized and pelletized to test ionic and electronic conductivity. This work was also applied to the development of tri-layer spinel structures, which would produce an all-solid-state battery with a solid-state spinel structured cathode, anode, and electrolyte.

I wish to acknowledge the mentorship of Dr Jan Allen.

Automation of Measurement Tools for Porous Silicon Characterization

Janelle Mabrey

Porous silicon is a unique material capable of producing high energy density, exothermic reactions when the pores are infused with a liquid oxidizer, such as sodium perchlorate. The energy release is triggered by a bridgewire that is integrated alongside the porous silicon. It is believed that passing a current through the bridgewire creates a localized hot spot and mechanically fractures the pores, causing the silicon fuel and oxidizer to mix. Because of the hygroscopic nature of the oxidizer, failures in both the porous silicon and the bridgewire affect overall reliability. Bridgewire health is typically diagnosed by measuring the electrical resistance, which is typically on the order of 3–4 Ω for good devices, whereas metal bridgewire delamination leads to resistance values on the order of megaohms. Current inspection procedures to evaluate reliability are conducted by hand with microscopes and stereoscopes, thus significantly limiting experimental throughput. In this work, a semi-automated system was demonstrated to collect still images of porous silicon devices to observe possible delamination of the bridgewire metal and surface cracking. A Raspberry Pi 4–controlled camera above a linear translation motorized stage was designed and demonstrated to collect still images with a graphical user interface. The images acquired will be used to further develop machine learning algorithms on the Raspberry Pi 4 to rapidly recognize surface cracking and bridgewire failures that impact device throughput for customer programs.

I wish to acknowledge the mentorship of Dr Wayne Churaman for his guidance and assistance during this summer internship.

Design of MAX Reinforced High-Performance Steel Composites for Sliding Applications

Caleb Matzke

In this presentation, I report the synthesis and characterization of steel matrix composites reinforced with 5 vol% chromium aluminum carbide (Cr_2AlC). Initially, the steel-based compositions were sintered by pressureless sintering using argon atmosphere at 1400 °C for 30 min. These samples were also heat treated at 840 °C for 23 min in air and then quenched in water. The Vickers microhardness is determined using a Mitutoyo HM-112 hardness testing machine. For microstructural evaluation, nital etchant (5% nitric acid–95% ethanol) was used to etch the surfaces of the steel samples for 4 s (non-heat-treated 52100 steel, 52100–5% Cr_2AlC , and heat treated 52100 steel) and 8 s (heat-treated 52100–5% Cr_2AlC). The etched surface was analyzed using an optical microscope under bright field and dark field. The samples were tested against an alumina ball using a CSM tribometer. A high-precision scale was used to measure the mass before and after the experiments to determine the wear volume. Detailed analysis of microstructure and wear results are presented.

I wish to acknowledge the mentorship of Stephen Berkebile, Surojit Gupta, and Nikhil Murthy.

Automation of Backface Deformation Tracking in Ballistics Gelatin

Adam Menkara

Gelatin-backed armor testing allows for the video capture of dynamic armor back-face deformation to assess behind-armor blunt trauma (BABT). Because the human body's response is rate-dependent, measuring the rate and depth of deformation are key factors to evaluate an armor's success. By tracking the leading edge of the deformation in the video, the rate and deformation profile can be calculated. Because the videos must be captured at high frame rates for ballistic impacts, the signal-to-noise ratio in the video images is low, making it difficult for computer programs to analyze individual frames of the video. Therefore, current analysis techniques use a time-consuming, primarily manual, procedure to track the leading edge of deformation. A new computer program was developed with an emphasis on detecting movement by finding differences across frames to identify the leading edge rather than looking at single frames. This method allows for a much less time-consuming and computationally intense tracking algorithm, reducing the time required to analyze a BABT video from 5 h to under 5 min. Furthermore, the algorithm was able to accurately track five of six dynamic armor back-face deformation profiles.

I wish to acknowledge the mentorship of Drs Karin Rafaels, Alan Goertz, and Cynthia Bir for their guidance and support throughout this project.

Terrain-Aware Costmap Generation for Unmanned Ground Vehicles Using Multimodal Inverse Reinforcement Learning

Ashwin Menon

Global plan efficiency for unmanned ground vehicles (UGVs) is of paramount importance in various scenarios: disaster relief, humanitarian assistance, and Soldier-robot teaming in contested areas, to name a few. In these situations, it is often difficult to anticipate the current state of the environment. Thus, UGVs need to behave robustly yet adaptably when navigating previously unexplored environments. As such, this research attempts to use two different types of human-robot interaction to robustly train robots to generate costmaps with greater optimality and enable greater adaptability. These two modes of interaction are human demonstration and intervention. Demonstration is the human proactively teleoperating the robot to teach it the optimal trajectory, while intervention is the human reactively teleoperating the robot to perform corrective action. Performance is quantitatively evaluated by comparing modified Hausdorff distances (MHDs) for three separate trajectories against a fully human-teleoperated ground-truth trajectory. The three aforementioned trajectories are as follows: demonstration-and-intervention (multimodal inverse reinforcement learning [mIRL]), demonstration-only, and intervention-only. We hypothesize that our experiments will show a non-negligible improvement in MHD metrics when comparing mIRL trajectories versus intervention-only trajectories, and a non-negligible reduction of training data needed when comparing the mIRL paradigm with the demonstration-only approach.

I wish to acknowledge the mentorship of Dr Maggie Wigness for her guidance during this past summer. Despite a few setbacks due to circumstances beyond her control, she was instrumental in ensuring that the internship process went as smoothly as possible. I would also like to thank DEVCOM ARL for offering a meaningful research opportunity that has a real, tangible impact on the US Army's Soldiers.

Effect of Sample Morphology on the Plasma Hydrodynamics of Alumina (Al_2O_3)

Clayton Miller

The hydrodynamics of the plasma resulting from a laser ablation event are highly complex and not completely understood. For this work, the role of particle size on the plasma hydrodynamics of alumina (Al_2O_3) after undergoing laser ablation was explored. Samples of nano- Al_2O_3 and micron- Al_2O_3 were prepared on double-tape affixed to a glass slide and shocked by a focused nanosecond-pulsed laser, forming a laser-induced plasma. Temporally resolved emission spectra were acquired for each sample to determine the species that emit during the subsequent exothermic reactions and what wavelengths would be of interest to image. Utilizing a high-speed framing camera with four intensified channels, different species within the plasma were simultaneously imaged using the appropriate bandpass filters for each channel. Species selected to be imaged in this study include aluminum (Al), Al^+ , aluminum oxide (AlO), hydrogen (H), and oxygen (O). Time regimes of a few microseconds and tens of microseconds were analyzed to study both the plasma and post-plasma combustion reactions. We found when Al_2O_3 is ablated, the spatial distribution of the product species is driven by different hydrodynamic mechanisms depending on particle size. The comparison of nano- Al_2O_3 and micron- Al_2O_3 demonstrates that Al and AlO consistently emit in plume locations.

I wish to acknowledge the mentorship of my advisor Dr Jennifer Gottfried and the help of her post-doc Dr Elliot Wainwright; the success of this research would not have been possible without their tremendous support and guidance. Throughout this program, they were key to my development as a researcher and have helped me become a better graduate student. Their unending patience was highly impactful to the quality of research I was able to conduct for this project. I would like to also thank Oak Ridge Associated Universities and DEVCOM ARL who made this internship possible. The opportunity I was given by them to work at Aberdeen Proving Ground and witness the high-quality research done by DEVCOM ARL scientists will help me in every one of my future endeavors.

Effect of Aluminum + Graphene Oxide Reactive Material Sample Preparation on Electrostatic Sensitivity

Kristi Naude

The current methodology used by the US Army to classify the electrostatic sensitivity of novel reactive materials involves subjecting a taped sample of the material to an electrical discharge of predetermined intensity. The conclusion regarding the sample's detonation (go) or non-detonation (no-go) is then determined by evaluating the cracks present in the tape securing the sample. Many factors can potentially skew the results of this method, such as cracks in the tape existing prior to testing and the personal conclusions of the individual conducting the study. This method of confirming the combustion event of the sample is consequently subjective in nature rather than being grounded in objective measurement criteria. The focus of this study was to establish objective measurement criteria to determine the go or no-go status of a sample under study, as well as determine the minimal energy sufficient to cause particular samples of interest to react. These criteria were developed using photodiode traces to confirm combustion events, with high-speed cameras supplying additional visualization, thereby removing subjective human influence from the evaluation process. This method developed was then applied to aluminum wrapped in graphene oxide, which is currently being developed at DEVCOM ARL as a metal additive.

I wish to acknowledge the mentorship of Drs Jennifer Gottfried and Elliot Wainwright.

Scene Understanding for Threat Classification for Natural Disaster Images

Abhay Patel

With the development of new computer vision techniques, the tasks that computers can perform when given an image expand greatly. When observing images of natural settings, these techniques can be used to perform scene understanding, allowing the level of threat in an image to be detected. This investigation aims to detect the threats in images of natural disasters using a computer vision model with a causal reasoning component. This approach first detects various objects in each image using a detection and classification hybrid model. Causal reasoning contextualizes this information to detect threats in the scene.

Additionally, we aim to make progress in detecting subtle visual cues that distinguish nonthreatening environments from threatening environments. Using a developed image classification model and observing the areas of key activation, the visual cues are not always detected. We expect to obtain better results with the proposed approach. We anticipate an improvement in model performance; however, we also anticipate limitations due to data set size and diversity. Furthermore, the subtlety of the visual cues is something the network likely will have trouble detecting, so further research will be needed to ensure the detection of such subtle cues.

I wish to acknowledge the mentorship of Adrienne Raglin.

Optimal Configurations for Floating Gate Transistors

Zuri Rashad

The production of semiconductors is critical to manufacturing all electronic devices used today, and the rapid advancement of technology has led to a necessity for transistors at an increasingly small scale. Current metal–oxide–semiconductor field-effect transistors (MOSFETs) only operate at two logic states and require an additional memory component to be connected in order to store information, which increases the number and size of transistors needed to operate a computer. The purpose of this study is to redesign MOSFETs into floating gate devices to create multiple memory states within a transistor and allow memory to be stored on the same transistor that operates logic. By combining multiple oxides with various bandgaps and stacking them between the gate and the substrate, electronic charge can be trapped between the gate and tunnel oxides and create an additional nonvolatile memory state, which remains even when the power source of the gate is turned off. DEVCOM ARL investigates the voltage mechanisms of semiconductor configurations including the elements hafnium oxide (HfO_2), aluminum oxide (Al_2O_3), tungsten diselenide (WSe_2), silicon nitride (Si_3N_4), and titanium oxide (TiO_2). The results demonstrate that the variation in the bandgaps between the oxides allow for a floating gate device to generate a voltage output even without connection to a power source, meaning a nonvolatile memory state can exist within the transistor.

I wish to acknowledge the mentorship of Sina Najmaei.

Investigation of a Manufacturing Technique for using Betavoltaics in Semiconductors

Jeffrey Read

Betavoltaics are a power source that harnesses energy from radioisotopes to produce electric power. Since radioisotopes emit high-energy particles for long periods of time, these devices are ideal for extended-duration sensing or medical implants. While semiconductor materials are readily available to harness the particles, consistent fabrication and packaging of prototypes is still a challenge and will require new manufacturing techniques for higher-density integration. Of the available semiconductor materials, indium gallium phosphide (InGaP) is best suited to our needs and is cheap and available. Current-voltage (I-V) curves were generated for 1-cm² semiconductor chips to determine diode quality and response characteristics. To contain the radioisotope on top of the semiconductor, we fabricated reservoirs from ultraviolet-cured resin in specially designed silicone molds. The mold required design of a 3-D-printed fixture. Reservoirs were sealed to the InGaP devices that were then mounted on copper ground planes. Wire bonding from InGaP to ground plane completed the electrical connection in the device fabrication process. With the device fully fabricated, we can add the radioisotope to complete the betavoltaic.

Future efforts will investigate stacking and their connections along with arrays toward the goal of 10-mW/cc power sources to operate devices for long-term military applications.

I wish to acknowledge the mentorship of Marc Litz.

Nuclear Magnetic Resonance (NMR) Structural Determination of a Cyclometalated Iridium(III) Complex

William Roberts

Cyclometalated iridium(III) complexes have a wide range of applications, with their most prominent being as phosphorescent dopants in organic light-emitting diodes (OLEDs). Recently, these complexes have shown promise as reverse saturable absorption (RSA) materials capable of undergoing a photophysical change upon photon absorption, increasing their affinity for further photon absorption. Despite the interest in these complexes, existing synthetic methods for them are fairly inefficient, commonly requiring reaction times of hours or even days. Increasing the synthetic efficiency of these complexes, therefore, is of great interest for applications in the Army, as well as in industry at large. Microwave-assisted organic syntheses (MAOSs) allow for decreased reaction times and alternative synthetic pathways due to their use of super heating of the solvent beyond its boiling point in a pressurized vessel. Reaching high temperatures, however, requires high-boiling-point solvents, meaning that solvent choice plays an important role in the success of microwave syntheses.

However, not all chemicals or reactions are amenable to elevated temperatures, as side product formation or even degradation of the starting material/product can occur under sufficiently extreme conditions. To optimize the synthesis of cyclometalated iridium complexes, the effects of solvent identity on the synthesis of $[\text{Ir}(\text{pbt})_2(\text{acac})]$ (where pbt = 2-phenylbenzothiazole and acac = acetylacetonate) were investigated. Both the relative purity of the resulting products and their crude yields were observed at various reaction temperatures. In addition to synthesis optimization, an in-depth structural analysis via nuclear magnetic resonance (NMR) spectroscopic analysis of the $[\text{Ir}(\text{pbt})_2(\text{acac})]$ complex was accomplished utilizing 1- and 2-D experiments. These results are useful not only for the synthesis of this specific complex, but should be general for this class of materials, which are also of interest for applications in the Army.

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Navigation Using Global Navigation Satellite System (GNSS) for Geofencing, Experimenting, and Testing (NUGGET)

Nathan Rogers

To improve the position and provide accurate geofencing for unmanned aerial vehicles (UAVs), Global Navigation Satellite System (GNSS) receivers that receive and track multiple GNSS constellations can provide more signals and more satellites, such as concurrent global positioning system (GPS), GLONASS, Galileo, and BeiDou plus SBAS and QZSS reception. The proposed Navigation Using GPS for Geofencing, Experimenting, and Tracking (NUGGET) system is a mobile, modular, waterproof (IP62) system with accommodation for various GPS/GNSS receivers, autopilots, and radios. The current size, weight, power, and cost (SWaP-C) configuration utilizes a uBlox NEO-M9N receiver, a 915-MHz radio, and a Pixracer autopilot in a 3-D-printed framework within a Pelican 1150 Battery Case. The precision of this setup has been demonstrated to be 2.0-m circular error probability (CEP) on a clear day. A new user interface using the Leaflet JavaScript library was designed to mark single and multiple deployed NUGGET systems in real time on a map. A new security layer was also compiled to provide RSA encryption over a wired connection. Since this NUGGET system is configured with the same architecture as a standard UAV, there is native support for communication between these systems for geofencing and validating geolocalization.

I wish to acknowledge the mentorship of Nassy Srour, Dr Joseph Conroy, and Paul Sabbagh.

The Effects of Level of Automation on Human Behavioral Measures

Aayushi Roy

Military planners increasingly view artificial intelligence (AI) as the key research area to compete with adversaries in Multi-Domain Operations.¹ AI developers tend to assume that AI should do as much as possible to relieve human performance requirements; however, this assumption is questionable and requires empirical investigation.² To investigate the extent to which AI should intervene for the most beneficial outcomes, our research team manipulated levels of automation and observed the effects on 40 subjects' accuracy, score, response time, trust in automation, system usability perception, and workload in a cyber-analysis experiment. Subjects scanned lists of alerts and looked for given target stimuli that indicated whether an alert was a Hit (a real threat) or a False Alarm (not a threat). The five levels of automation³ ranged from Manual Control (Level 1), where there was no AI intervention, to Consensual AI (Level 3), where the human and AI collaborated evenly, to Full Automation (Level 5), where an AI selected the correct response 80% of the time. More research must be conducted, but initial results suggest complete AI intervention and maximal collaboration between AI and humans produce the best outcomes. We hope to transition future results in our collaborators' organizations at the Program Manager Mission Command and West Point's Army Cyber Institute.

I wish to acknowledge the mentorship of Dr Dan Cassenti, Dr Rob Thomson, and Thom Hawkins.

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Tracking Perceptual Depth with Eye Vergence and Inter Pupillary Distance in VR

Mohammed Safayet Arefin

Virtual reality (VR) technology has been increasingly used in a variety of contexts including immersive training as well as investigating research questions across a variety of fields such as perception, psychology, cognitive science, and vision. In addition to VR, another rapidly expanding technology is eye tracking. Eye tracking has enabled researchers to understand how the human visual system functions and acquires information from the environment. However, how our visual system behaves in the context of objects changing depth in VR is still an unexplored research area. This area of research is underdeveloped because only in the past few years have combined eye tracking and VR systems become commercially available. One potential use of eye tracking-enabled VR technology is to track which depth participants are looking at and present stimuli according to the perceptual depth so as to reduce switching between visual depth planes. Therefore, the primary purpose of this work is to investigate whether perceptual depth can be estimated using the eye tracker data in VR. We considered a visual discrimination task with an HTC VIVE VR head-mounted display that uses Tobii eye-tracking technology. Two depth-dependent human visual system components (eye vergence and interpupillary distance [IPD]) were computed independently from the eye tracker data for estimating the perceptual depth changes in VR. Results of our study indicate that when subjects shifted their gaze from the far distance to the near distance, the vergence angle increased and IPD decreased. However, we observed the opposite pattern of vergence angle and IPD when shifting gaze from the near distance to the far distance. We also found that virtual information in the retina's periphery region was observed perceptually closer than the foveal and parafoveal regions. Our analysis implies that our implemented method successfully estimates the perceptual depth changes in the VR environment using eye tracker data. We believe that the results of our study will become a new tool for VR and augmented reality developers to render virtual objects according to the perceptual depth plane, and eventually improve the user experience in VR.

I wish to acknowledge the mentorship of Russell Cohen Hoffing.

Network Model Adaptation via Online Region Segmentation

Matthew Schack

Robotic teaming requires robots to move and communicate with one another to transmit locally sensed information to the other team members. However, modeling where robots can communicate from is a challenging problem due to environmental characteristics (e.g., walls or other obstacles). We present a network modeling approach that decomposes the environment into regions of space where communication between and within regions can be modeled using linear functions. Our approach uses sampled signal strengths obtained online to ensure the created model is accurate for the given environment, and by partitioning the environment into regions, we improve the scalability of the method to larger environments.

I wish to acknowledge the mentorship of Dr John Rogers for his guidance and help during this project.

Comparison of Cycle-Generative Adversarial Network (GAN)–Generated Synthetic Data on You Only Look Once (YOLO) Object Detection

Avik Singh

Object detection is an important tool that can be used to track multiple key interests without the need of human intervention. This can be achieved through development and training of artificial intelligence (AI) systems designed to help users identify and track objects given a large amount of data. The You Only Look Once (YOLO) object detection system is a public repository that allows users to identify objects in an image. Development of such systems requires the AI to train over multiple iterations of object-based images to fully comprehend the object and how to find/track it given new images. The amount of preliminary images required to develop these systems is currently sparse, so a new method of achieving data is necessary. This can be achieved through synthetic data generation. One promising way to generate synthetic data is using Cycle-Generative Adversarial Networks (CycleGANs) to transform one type of image into another. Therefore, we can use this to generate infrared (IR) data given electro-optical (EO) data and use that to train YOLO. To test this method's effectiveness, we need to compare this to real-world IR data to determine its use cases. Experimentation is needed to find the optimal conversion from EO to IR, but ultimately, this process will help to facilitate our understanding of synthetic data generation.

I wish to acknowledge the mentorship of Dr James Uplinger.

Information-Directed Reinforcement Learning for Autonomous Reconnaissance and Patrol

Wesley A Suttle and Ji Liu

Reinforcement learning (RL) encompasses a wide range of techniques enabling autonomous agents to learn from experience how to operate effectively in unknown and potentially hostile environments. Since the environment is initially unknown, an RL agent must balance obtaining information about the environment with exploiting its current information to minimize costs. This exploration–exploitation tradeoff is a perennial and widely studied issue in the literature; many methods encourage information acquisition to eventually learn a lower-cost control policy. No methods yet exist, however, that explicitly optimize the cost per unit information acquired about the environment. Motivated by the information-directed sampling scheme of Russo and Van Roy,¹ treatments of entropy maximization,^{2,3} and RL for ratio optimization,⁴ we propose the following novel objective for the RL setting: given a policy, define its information ratio as the ratio of its average cost to the entropy of the state occupancy measure it induces. This objective can be interpreted as the expected cost per unit information obtained about the environment when using the policy and can be used to model problems of interest, including patrolling an area of operations (AO) while eliminating targets and reconnaissance of an AO while avoiding detection.

We developed RL algorithms for minimizing that information ratio, elaborated the underlying mathematical theory, and performed numerical experiments indicating promising performance. First, we proved an entropy gradient theorem to sample from the gradient with respect to the policy parameters of the entropy of the induced state occupancy measure. We then used our entropy gradient theorem to formulate policy gradient algorithms for finding the optimal information ratio. Next, we derived a concave program to determine the optimal information ratio and corresponding policy when the dynamics and costs of the environment are known. Then, we implemented our algorithms, a framework for leveraging DOD compute resources to run large batches of experiments in parallel, and a solver for the concave program. We numerically demonstrate our algorithms find the global optimal solution in the tabular setting. We empirically demonstrated, given the same hyperparameters, our actor-critic algorithm far outperforms a vanilla actor-critic when solving an array of different maze problems. Ongoing work includes performing theoretical convergence analyses of our algorithms, implementing practical versions using neural networks as function approximators, and developing reconnaissance and patrol problem simulators for evaluating our algorithms. Future work includes deploying and evaluating our algorithms in real-world systems.

I wish to acknowledge the mentorship of Alec Koppel.

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Fast Charging of Lithium-Ion Pouch Cells as a Function of Elevated Temperature

ViChi Tran

Lithium (Li)-ion batteries demonstrate high energy density and good cycle life under low to moderate charge rate conditions but tend to suffer rapid capacity fade and safety problems under fast charge. Fast charging of Li-ion batteries provides promising capabilities for Army applications and the electric vehicles (EVs) market. To understand some of the limitations of Li-ion cell charging, two types of Li-ion pouch cells of similar size and construction were tested under different fast charging rates (full charge in 6 to 30 min) over a range of temperatures (20 to 60 °C). Data was collected and evaluated as a function of the batteries' discharge capacities and energy.

I wish to acknowledge the mentorship of Dr Jeff Read, for providing guidance throughout the entirety of the internship this summer. He has taught me everything that I know regarding this project and research, and I am extremely grateful for his patience and assistance when I required it in the process. It has been an honor to study and work beside Dr Read. Thank you.

Evaluation of Fatigue and Wear in High-Pressure Fuel Pump Check Valves

Andrew Velasquez

Wear over the course of time will eventually lead to failure in a component, compromising the reliability of the system. Oils are a common lubricant applied to moving components to reduce the onset of wear, but oils cannot be used in high-pressure fuel pumps due to the oil compromising the fuel formulation. The only source of lubrication is the fuel used in the fuel pumps of the vehicles, providing minimal lubrication between moving components in the pumps such as the repeated ball impacts during the moving of fuel in check valves. Studying impacts in different fuels is necessary to reduce wear of essential operating components. An impact apparatus was designed using a combination of machined aluminum beams and a microcontroller to initiate commands to a solenoid and load cell. A ball being driven onto a material submerged in fuels against the load cell was used to replicate fatigue and wear in check valve of fuel pump. Evaluation of wear on impacted material is analyzed using optical microscopy and interferometry to view the surface morphology.

I wish to acknowledge the mentorship of Ashlie Martini, Monica Ferrera, Kevin Kamrar, and David Gondol.

Developing a Property Linked, Parameter-Driven Model of Ultra High Molecular Weight Polyethylene (UHMWPE) Plate Material

Travis Wagner

Ultra high molecular weight polyethylene (UHMWPE) plate material is a highly anisotropic composite used in various armor applications. The material comprises two main parts, the UHMWPE fibers and the matrix within which these fibers are constrained. The material is highly modifiable, mainly by changing the fibers, the matrix, and the consolidation process. The goal of this project is to further the development of a model that has input parameters that are linked to the physical properties of the material. This will allow the model to both predict experimental performance and suggest change in the manufacturing process.

Modeling each fiber and matrix layer explicitly is limited by computation; therefore, a homogenized material model is used to represent multiple layers at once. This homogenized material model¹ represents the contributions the fibers and the matrix have in the mechanical behavior, along with other mechanisms present between the two materials. The model was fit to the load response and strain contours of short beam shear and three-point bending experiments. Modeling two similar experiments with different geometries tests for model robustness that cannot be determined from a single experiment. The model was changed to add a different fiber modulus that becomes active under compression, which is being validated by ongoing experiments. The model was also edited to include a strain hardening effect into the slip mechanism.

I wish to acknowledge the mentorship of Dr Richard Becker for working with me through the summer and Dr Daniel O'Brien for providing the experimental data.

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Effects of n-Dodecane Soaking Time on Friction Performance and Wear on Stainless Steels

Harry Wise

Current Army fuel pumps experience wear at metal interfaces that move in relation to one another. They are lubricated with low-viscosity hydrocarbon-based fuels. Carbon (C) tribofilms are formed from the fuels under enough pressure and with a sufficient flash point temperature at the asperities of the surfaces in contact. These tribofilms are dense, solid layers of amorphous, diamond-like carbon (DLC) with low-range crystalline order. DLC films are known to reduce friction caused by asperity contact at interfaces due to their high hardness and elastic modulus. Low-viscosity lubricants can outperform higher-viscosity ones in terms of coefficient of friction and wear resistance when DLC tribofilms are formed. From the literature, steels with additives such as copper (Cu) and nickel (Ni) catalyze the tribofilm reaction by dehydrogenating the alkanes (of which dodecane is primarily composed), after which scission of C–C bonds can occur, forming shorter branch alkanes. Nucleation and growth of amorphous carbon can then occur. Further, surfaces that favor carbide formation inhibit the dehydrogenation activity of the surface and reduce tribofilm formation.¹ Our experiment seeks to establish a black box model relating soaking time and temperature of the lubricant on the metal interface to friction performance under tribometer tests. My working hypothesis is soaking time and temperature are proportional to the amount of adsorption lubricant molecules experience at the surface, causing a reproducible decrease in the coefficient of friction and total wear volume. This black box approach avoids characterizing tribofilm formation and adsorption dynamics via molecular dynamics on all types of substrates, limiting our testing to three types of steel with one lubricant. To do this, we test flat samples with lubricant in a tribometer with a ball made of AISI 52100 steel. The ball scratches a 10-mm path on the sample surface with a 2-N vertical load and 5-Hz frequency. Samples of 52100 steel are soaked with dodecane for 0, 0.5, 3, 15, and 24 h. Each sample is standardized to an average surface roughness (Ra) of 20.2 ± 2.7 nm and Vickers hardness of 374 ± 18 HV_{0.3}. We use n-dodecane of 99% purity, meaning primarily composed of alkanes with possible impurities made of alkenes and shorter chain alkanes. It is yet unclear whether friction reduction can be attributed to increased adsorption of n-dodecane or adsorption of the impurities. With greater adsorption to the surface, tribofilm formation occurs quicker and in greater quantity. However, our data thus far may indicate extended soak times (15 to 24 h) allow too much adsorption leading to poorer friction performance versus soak times between 0 and 3 h. This will be confirmed via molecular dynamics simulations and further tribotesting. Isolating soak times that are ideal for friction reduction will lead to testing under different temperatures. AISI-52100 steel is our baseline, containing

chromium (Cr), C, and manganese. We will compare the friction performance of 52100 to D2 (high Cr content with added molybdenum) and CF2 (custom formula containing Cu, Ni, and C) to explore this hypothesis.

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Heart Rate Synchrony Using Multidimensional Recurrence Quantification Analysis

Julie Young

Utilizing previously collected preflight test data of crews operating ground vehicles in a simulated combat mission for varying crew configurations, we compared pairs of operators' data through Multidimensional Recurrence Quantification Analysis (MDRQA). The data was acquired using a lightweight wireless sensor belt (Zephyr Bioharness) that transmitted electrocardiogram waveform, interbeat interval, respiration waveform, and three-axis accelerometry. Applying MDRQA, patterns of coordination can be found between operators and can indicate teamwork and trust building between operators. Therefore, matched dyad pairs are expected to have a higher recurrence than unmatched pairs. First, an open source MDRQA algorithm was tested using artificial signals; synchronous signals with high recurrence created a highly populated recurrence plot and metrics indicating high recurrence, whereas asynchronous signals with low recurrence created a sparsely populated plot and metrics indicating low recurrence. The algorithm was applied to the data for each of the matched and unmatched pairs of vehicle operators and did not result in any appreciable difference in their recurrence plots or metrics, and therefore synchrony or trust building, between the respective pairs. This can be attributed to the fact that the data was in limited quantity, contained high levels of noise, and contained limited variation in trust and teamwork manipulation during interactions.

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The Effects of Aluminum Gallium Nitride (AlGa_xN) Schottky Diodes on the Impact of the Internal Maximum Electric Field

Jay Yun

This internship project investigates the impact of the alloy composition on the electron affinity, energy bandgap, and barrier height of aluminum gallium nitride (Al_xGa_{1-x}N) Schottky diodes. The investigated material parameters are used to compute the effective internal maximum electric field under different bias conditions. The properties of the alloyed Al_xGa_{1-x}N Schottky diode have been experimentally investigated before, in the early 2000s, where electric engineers would discover the electronic properties and electron affinities of Al_xGa_{1-x}N surfaces when investigated by an ultraviolet photoemission spectroscopy. To figure out the properties of the Al_xGa_{1-x}N Schottky diodes and their internal peak electric field, I used MATLAB to calculate the barrier height, the energy bandgap, the electron affinity, and ultimately the maximum electric field as a function of alloy composition. This work is relevant to power electronics because the peak field (critical field) is an important parameter needed to evaluate the figure-of-merit of materials. As the next steps, I want to understand the characteristics of the Al_xGa_{1-x}N Schottky diodes, more specifically, their turn-on voltages, recovery time, and energy at high frequencies.

I wish to acknowledge the mentorship of Franklin Nouketcha for working with me on this AlGa_xN project. He has helped me get a better understanding on how Schottky diodes function, how to implement complex MATLAB coding, and what it takes to be a part of the DEVCOM ARL team. He has given me a great understanding on what it means to be a researcher and how much work researchers put into projects. I would also like to thank Anand Sampath for putting the time and effort to catch up on what I have accomplished and what my next goals would be to accomplish each part of the project. Even with his busy schedule, I appreciate him always putting in time to make sure I am doing my job as a researcher in the best way I should be. Both of these people have been a huge asset to completing my research to the best of my abilities, and I am grateful to have worked with them side by side.

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