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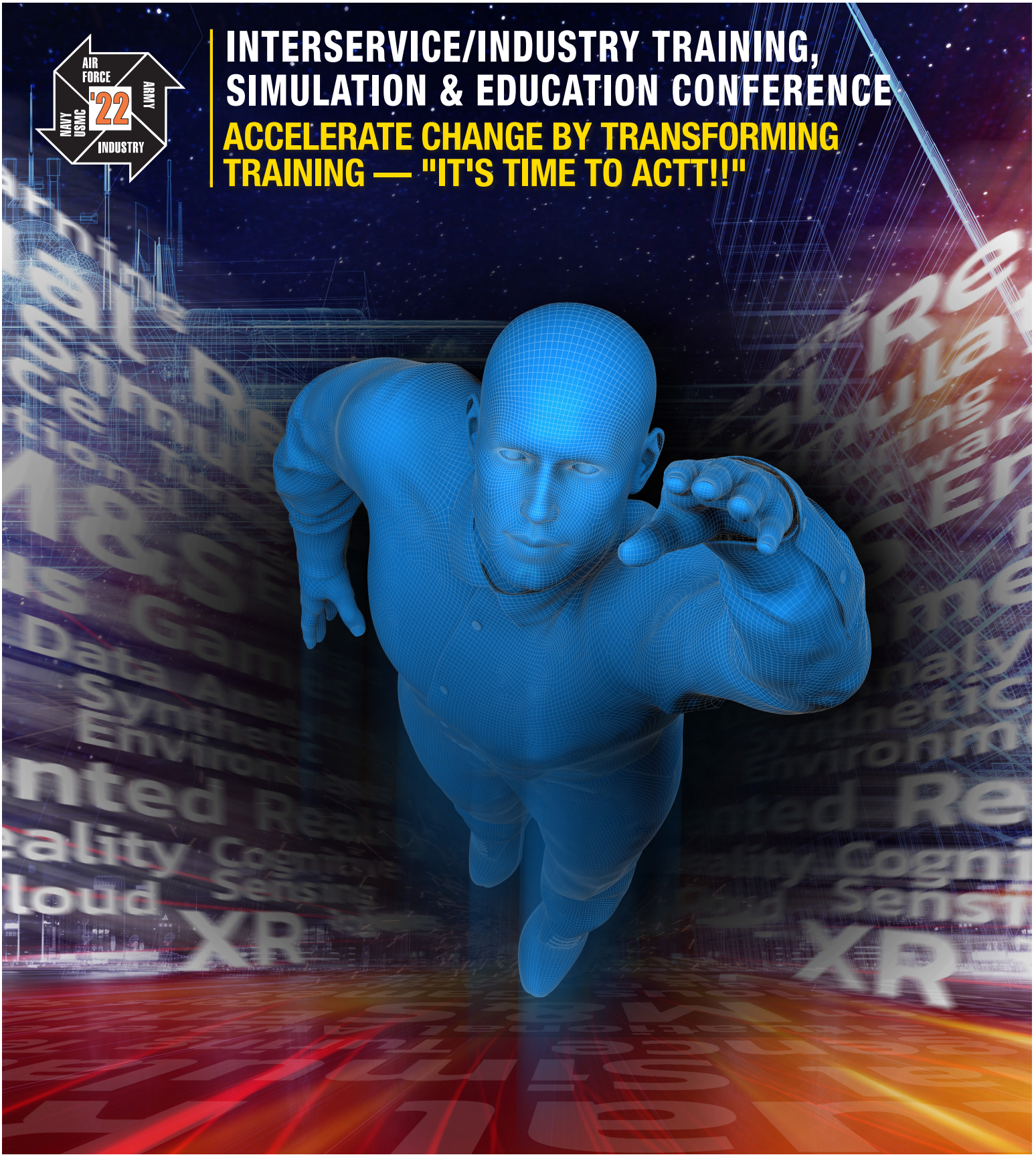

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How, When, and What to Adapt: Effective Adaptive Training through Game-Based Development Technology

Summer Rebensky, Ph.D., Samantha Perry, Ph.D., Wink Bennett, Ph.D.

22218

Adaptive training provides opportunities to administer learning or training content to the right people at the right time. This form of training has many benefits including more rapid skill mastery, optimal challenge level or engagement. An instructional designer can adapt training through the content itself - such as creating a more difficult environment -providing autonomy to the trainee, or providing interface display features or feedback to assist trainees (Zahabi et al., 2020). Adaptive training can also take place within a training instance or across trainings. This presents many opportunities to intervene and improve training but should only be implemented on elements that serve the training goals and at the right time. Considering adaptive strategies can, in some instances, increase training time (Sampayo-Vargas et al., 2013) and at times may incur higher development costs, it is important to ensure that instructional designers aim to implement adaptive capabilities where value can be gained. In addition, newer technological advances in simulation technology, physiological sensors, and integration technology allow for the assessment of trainee states live and unobtrusively. We posit that these technologies can mitigate the potential negative impacts of adaptive training and instead provide the users with real-time adaptations and in meaningful ways to serve their training goals. This paper will discuss different methods and approaches for adapting training content and provide guidance for the right implementation of various adaptive strategies. A low-cost experimental adaptive research testbed will be presented, allowing for the exploration of different strategies for measuring and adapting content utilizing game-based development technology. Discussions of the benefits and shortfalls of different adaptive decision logics, criteria, and adapted content will provide training designers with guidance on which adaptive strategies to use, under what conditions, and how to implement these strategies in modern training environments.

Machine Learning For Automated Generation of Multiple Choice Test Items

Sowmya Ramachandran, Jeremy Ludwig

22133

Effective assessments are essential for training and personnel development. Developing quality assessments is labor-intensive. This could lead to a shortage of assessments that can significantly impact the Army's ability to develop their personnel and a Soldier's ability to plan their career growth. There is a unique opportunity to harness the powers of data science and artificial intelligence to address this problem. Recent breakthroughs in neural network technologies have led to stunning successes in natural language processing techniques (NLP). Neural network architectures like the Transformer, and the availability of vast amounts of digital natural language data have led to the creation of highly effective, pre-trained task-independent language models. Once trained, these models can be applied to any number of natural language processing tasks. All this raises an interesting question: are these approaches sufficiently rich to automate the task of generating assessments? The language models seem particularly useful for automating the generation of multiple-choice items to test recall and comprehension as a starting point of this investigation. This paper will describe an investigation into this question. Specifically, we use pre-trained language models like BERT (Bidirectional Encoder Representation from Transformers) that have been fine-tuned to tasks like question generation, question answering, and summarization. We combine this with traditional approaches like rule-based pattern extraction to generate a range of question types. Success of this approach will offer benefits such as tool that will enable assessment creators to draw from a high-quality, automatically generated question-bank. In this paper, we will examine the feasibility and effectiveness of this approach and to identify gaps and challenges. We will describe the models and algorithms that we have implemented and analyze their effectiveness and describe results of formative evaluations of the quality of generated content.

Can you Standardize Military Health System Training and Education Data Collection While Allowing the Services to Control how Training is Administered and Conducted?

Amanda van Lamsweerde, Erin Baker, Jeffrey Beaubien, Ph.D., Ruben Garza, Brett Lord, Sandra Hughes, Michael Guest, Cali Fidopiastis

22228

The Military Health System (MHS) currently faces a number of infrastructure challenges pertaining to learning and performance improvement. Currently, the MHS processes and systems in place cannot report enterprise-wide education, training, and human performance metrics. For example, across the Services and DHA, multiple training and education systems are used to collect data using different methods, resulting in a multitude of formats. These isolated, disparate, stove-piped systems do not have sufficient connectivity and interoperability to exchange data and information or produce integrated analytics that represent the systems as a whole. This lack of MHS training data infrastructure results in a subpar ability to report enterprise-wide education, training, and human performance metrics. The question here is: with over 30 systems across multiple Services holding data, Is it possible to create an enterprise-wide data strategy that allows for data to be collected in a standardized way across the Services while allowing each Service the freedom to control how training is administered and conducted?

This presentation will review research conducted across the Services to 1) understand how competence is evaluated across the Services, 2) what data is used to determine competence, and 3) where that data is stored. Results gathered were put into a cluster analysis to create a standard strategy to collect relevant training and education data, standardize it, and store it in a centralized location.

Redefining Journeyman and Master Craftsman Competency Models

Ted Dennis, Deri Draper-Amason, Ph.D., Katherine Smith, Jessica Johnson

22251

This paper represents a preliminary model of practiced stackable competencies to support the definition of a journeyman and master craftsman in real time. Numerous competency models exist and are relatively static. Our proposal is to inject real time proficiency data "sets and reps", of the craftsperson into the competency model and provide a better representation of the skill level of the individual.

Most competency models rely on a one time proficiency demonstration. While this may be effective for a baseline of the journeyman or master craftsman this falls short in defining the true skill level of the individual. Including documented sets and reps along with frequency of proficiency demonstration provides a more true analysis of the individual. Consider a master craftsman who's only qualification is a one time demonstration of the competency several years prior. We must consider the atrophy of a competency gained as time between mastery and repetition increases. When was the last time the individual practiced the competency and have there been changes in the competency that makes the years old qualification out dated and potentially null and void? When should a master craftsman be down graded to journeyman?

These questions can be answered through the use of artificial intelligence. The workforce data that is now available and easily obtainable can provide the necessary analytical data to gain a deeper definition of when proficiency of an individual competency is earned or, when it is lost. Our proposed model and associated rubrics will inform on the number of sets and reps required to determine mastery of a competency. The model will also determine a potential degradation cycle of competency proficiency. We will also recommend other competencies that are relatable and stackable to create a more realistic definition of a journeyman or master craftsman.

The Future of U.S. Air Force Public Affairs Media Training Using Real-Play Immersive Technology

Lori Hodge, Andrew S. Clayton

22256

In this era of strategic competition, U.S. military strategic effects are not just about munitions striking targets; they are about ensuring publics are informed in an accurate and timely manner. In a hostile environment, non-kinetic strategic effects could exceed the importance of kinetic operations. For this reason, U.S. Air Force Public Affairs needs to invest in the training of its spokespersons, or those deemed to communicate Air Force key messages, control the narrative, and answer questions from the press. Public Affairs professionals are focused on credibility and transparency, informing key audiences about military operations, and undermining adversarial propaganda. To maximize the benefits of the pedagogy used by Public Affairs professionals to train spokespersons to engage with media effectively, it is necessary to consider the learner's skill set to determine the level of realism of the task presented. This paper proposes a framework for instructional design which integrates real-play through the lens of flow theory for the purpose of considering the learner's skill set to determine the level of realism of the task presented in Public Affairs media training. This framework should assist leaders in identifying real-play scenarios that increase the student's challenge at the appropriate time, thus putting them in an optimal state of flow and increasing Air Force spokespersons' performance.

A Multi-Method Learning Framework for Multi-Capable Airmen

Richard B. Ayers

22265

The Air Force is transforming the way Airmen learn through opportunities that allow Airmen to train as they fight using experiential and multi-modal options. Concurrently, the Air Force is rapidly adapting to the challenges of the future security environment, where it should draw upon situated learning (SL) theory (Lave & Wegner, 1991) as a framework for training Multi-capable Airmen (MCA). Supporting the concept of Agile Combat Employment (ACE) through deploying in smaller, agile teams, MCA must perform tasks outside their core specialty, and a recommended method for training MCA to perform these new tasks is through SL-based learning. The Air Force is also accelerating change through increased use of virtual reality (VR) technology, which is well suited to experiential learning (EL) (Kwon, 2019). However, these new methods introduce new challenges to the Air Force. A review of literature finds that most VR applications focus on learning outcomes without supporting learning processes like EL (Fromm et al., 2020). Few studies exist on combining SL and EL using VR-based training. The Air Force is increasing its use of EL, yet it must go beyond the mode of the VR experience and leverage all four learning modes as described in Kolb's (1984) EL theory. By designing SL-based VR training around EL as a process, MCA will be able to cycle through the four learning modes (i.e., concrete experience, reflective observation, abstract conceptualization, and active experimentation) which can accelerate new skills by allowing them to learn from their own virtual experiences (Kolb & Lewis, 1986). Drawing on data available through open source, the paper develops best practices for SL and EL integrated with VR technology. This analysis will develop principles to inform and guide MCA instructional design and present recommendations on how to establish effective MCA training.

Influence of Physicality on Neuroplasticity and Cognitive Gains in Virtual Environments

Leslie Van Peteghem, Andrew S. Clayton

22271

The Air Force is researching the viability of Virtual Reality (VR) technology as a method to train and treat our service members and civilians. Increasing receptiveness to training and treatment through electronic means is becoming more crucial in our globalized society where the work/home environment may be geographically separated, or personnel may not be physically accessible for training or treatments. Traditionally, computer/lecture-based training and in-person treatment methods have been used as a way to pass on knowledge and assess health in the workforce. While effective for many, introduction of alternative learning methods such as active learning or gamification within a VR environment can provide interactive methods for self-improvement for the users regardless of location (Brame, 2021; Paul, 2021).

As interfaces and VR systems are researched and designed to accomplish training and treatment tasks, purposeful design, and integration of physicality within the virtual environment must be applied. Physical engagement employing various methods, intensities, and durations have been proven to yield cognitive gains and influence emotions of the user (Hilton, 2015 and Kramer 2007). Applying gained knowledge from basic physio-psychological studies to Virtual Environments can enhance and reinforce the interactive audio-visual effects of the environment and increase the learning/treatment experience and retention of the user (Shochat, 2017). Application of physicality within a VR environment enhances the success of the training or treatment by stimulating neuroplasticity, cognitive gains and emotions through physical reinforcement.

Can Priming Learners Prior to Learning Lead to Higher Learning Gain?

Tavion Yrjo , Nir Keren, Ph.D., Angela Leek, Peter Evans, Andrew Lawson

22277

Tremendous efforts and resources are funneled towards increasing engagement in learning through gamification or the use of technology such as extended realities. However, a literature review raises a concern that engagement has become an end goal that might overshadow the ultimate objective of enhancing learning and increasing educational transfer. Furthermore, there is a concern that engagement during learning results in distractions due to the need to devote cognitive resources towards engaging in the tasks at hand. These cognitive resources are then not available to maximize learning. This may be of further concern when the learning task is not straightforward but is more complex and requires a higher cognitive workload during the learning, such as the case with learning and training to conduct risk assessments.

Could priming learners prior to learning lead to higher learning gain?

A two-phase approach is taken to examine the question above: (1) priming learners; (2) learning engagement. The priming phase consists of three settings: gamified, entertainment, and utilitarian. The learning task is to assess VR environments for noise exposure risk. In the gamified setting, learners will engage in assessment while receiving real-time feedback, with a performance-based monetary reward. In the entertainment setting, students assess risk in an entertainment center with noisy elements such as arcade machines, jukeboxes, and speakers. Real-time feedback will not be provided. In the utilitarian setting, learners conduct a risk assessment task in a VR industrial environment with neither gaming nor entertainment elements. Here too, real-time feedback will not be provided. All three priming settings will be short.

The learning engagement phase will immediately follow the priming phase. Here, all learners will engage in a risk assessment task in a utilitarian setting. Comparing the quality of the assessments among the three settings will document the effect of the priming setting on learning gain.

Modernizing High-End Flight Training for the Contested Fight

JJ Walcutt, Ph.D., Jay Spohn, Thomas Harley

22284

Historically, flight training has focused on creating pilots who can master the ability to handle a variety of environmental, human, and technological risks to complete pre-planned missions. Yet, as technology advances have become shared across both allied and adversarial forces, the contested fight is being realized. To be specific, the additional skills and competencies needed to be effective in the future fight are categorically different than the primarily flight-focused skills previously required. Accordingly, the USAF has created the opportunity for instructors to define readiness independently, differing from the Ready Aircrew Program (RAP) Task Messaging historical requirements. While this is a first step to recognizing that current metrics and matrices are not representative of all the nuances of the skills required for aircrew readiness, there needs to be a definition and associated assessment method that targets these new, and more complex, competencies.

In response, the USAF completed a learning engineering study for one airframe to determine how to modernize learning practices and inform technology requirements. Subjective data was gathered to first understand the competencies needed to be ready for the "Night One" future fight. Second,

these findings were translated into a five-stage model of development which was then used to create an updated set of learning goals and metrics that can influence training content, pathways, and technology procurement decisions. This paper will provide an example for how to modernize training for the contested fight. It will focus on determining when and how to use live-fly or simulation-based training as well as what devices, environments, and other training elements are needed from industry.

Challenging the Status Quo in Nursing Education: Digital Transformation with Virtual Reality

Juliet Kolde, Jeffrey Olsen, Jack Pottle, Molly Schleicher

22342

Nightingale College's continuous focus on innovative, evidence-based design keeps the organization on the forefront of challenging the status quo and pioneering new higher education approaches. The College is currently facilitating a multiphase VR pilot program to deliver a hands-on, simulated nurse training environment. The College's partnership with Oxford Medical Simulation (OMS) and the Meta Quest 2 Virtual Reality Goggles allows learners to apply their skills and knowledge in the safety of a virtual environment that mimics real-life nursing situations. They are immersed in typical nursing scenarios, including diagnosing patients, instigating treatments, and interacting with the interdisciplinary team. They may repeat experiences as often as they like, with the system offering multiple adapted outcomes based on their responses to fully interactive, simulated patients and their family members. They also receive personalized feedback, performance metrics, and a guided self-reflective debrief. Although the Nightingale College pilot program is still in its infancy, initial results are demonstrating excellent student feedback and improved outcomes in critical thinking and clinical reasoning. Future plans include expanding use of the OMS scenarios to include more learners and other courses. The College, unrestricted by traditional methods of instruction, continually searches for new ways to innovate in nursing education through its full-distance education model to improve outcomes and solve issues across the nursing profession, including the nursing shortage. This allows for effective execution of the institutional mission and contributes to the realization of health equity.

Within this paper, the authors will discuss the differences between VR simulations versus on-ground simulation experiences, review development of the pilot program plan and describe the multiphase approach toward implementation. Additionally, the authors present a review of initial outcomes and testimonies of learner experience throughout the pilot program and examine the learners' improvement in clinical reasoning skills with VR simulations.

Implementation and Importance of Science of Learning Best Practices within Learning Organizations

Robert Siegle, Scotty Craig, Noah Schroeder

22467

Technology is rapidly transforming how people learn and how we provide training. This substantial number of students accounts for 33.7% of the current student population (National Center for Education Statistics, 2018, Table 311.15) and are part of a two-decade long growth trend for online learning. The Science of learning and Readiness (SoLaR) project provided specific guidance on metrics-based, most effective, at scale, and blended learning strategies within institutional systems, courseware, and pedagogical methods. Along with many specific examples of best practices, the project found four core principles (1) fundamental principles of human learning from the learning sciences are applicable to blended and learning-at-scale environments, (2) human learning within these environments must be supported by technology, (3) the technology must report data on the learning process to the learning organization, and (4) learning organizations must use data to (a) support learners with learning, social, and academic guidance, and (b) support members of the learning institutions with training, support, and recognition.

To further understand perceived importance and implementation of these practices, we surveyed learning organizations representing public, private, and academic sectors. We observed a consistent discrepancy: respondents reported that actual implementation of best practices fell short (i.e., ratings of implementation were significantly lower than ratings of perceived importance). This pattern was most striking within military organizations. The survey sample was small and thus limited in generalizability. Nonetheless, the consistently high perceived importance of best practices in the public sector—particularly the military—suggest a readiness for a transition to advanced distributed learning methodologies.

EMERGING CONCEPTS AND INNOVATIVE TECHNOLOGIES

BEST PAPER

Building a World With Deepfake Content – Who Needs Real Data?

Graham Long

22190

Synthetic content can be artificially produced, manipulated, or modified using artificial intelligence (AI) to create a wide range of synthesized data from text, prose, music, or images to videos. When used for a malign purpose to mislead or deceive, this synthetic content has come to be known as "deepfakes". But beyond the potentially sinister, headline-grabbing generation of fake videos of world leaders, deepfake technology can be applied to create content and data valuable to the construction of synthetic environments.

Data describing the physical world is now very abundant and provides a rich data source to support synthetic environment development. Still, there are many scenarios where this data may not be available or suitable. In these situations, artificially created data can provide data where none exists, augment existing data, improve data quality to provide accurate representations of real features, data and places, or even create entirely fictitious data and environments.

Generative artificial intelligence is one of the most promising advances in AI in the past decade. Generative models produce synthetic content by learning to mimic a data distribution and generate new, similar, credible content. For example, they can create entirely artificial satellite imagery, increase image resolution or remove artefacts within painting. They can also generate or manipulate other data types, such as land cover, point clouds, maps, 3D models, or even the design and style of the entire environment, all of which will appear authentic but are, in fact, entirely artificial

This paper will explore the current state and capabilities of generative models. It will identify those model types, such as Generative Adversarial Networks, that are most suited to generating synthesized content for synthetic environments. Finally, it will illustrate how these models can be applied to specific types of content and use cases and evaluate the currently achievable results.

Recommendation System in an Integrated Digital Training Environment for the 5th Generation Air Force

Dirk Thijssen, Rik Bosma

22106

To ensure readiness of the 5th generation Air Force weapon platforms and systems, maintenance personnel must be able to quickly adapt to new competency and qualification needs. To effectively meet these demands, the current training for maintenance personnel must change from a formalised, classroom, pre-planned and one-size-fits-all training strategy to a more distributed and personalised training strategy. This requires not only a new way of training but also requires the deployment of complex technologies.

The IDTEAM project explores the possibility of a personalised training strategy and an integrated digital learning environment. Based on user-oriented use cases, technology demonstrators are being developed to evaluate the Total Learning Architecture (TLA). The technology demonstrators contain a performance observation application, a game for maintenance pre-

flight check, xAPI2 link and a recommender system. In this paper we will briefly touch upon every demonstrator and will elaborate on the innovative recommendation system.

The recommender is a system that uses learner performance to recommend the next learning task that is most suitable to the learning need of the student. The recommender is built upon educational principles and translated to a technical application with the use of a progressive scoring system. The recommendation system provides a personalized learning trajectory based on competencies regarding large datasets and many learning tasks. The recommendation system also provides innovative evaluation techniques of the training curriculum.

Detecting Patterns of Life Using Deep Learning

Javier Garza, Patrick Rupp, Anastacia MacAllister, Ph.D.

22111

Commercial and government organizations are now collecting 100 terabytes or more of overhead imagery via satellites and drones on a daily basis. Specifically, within the Department of Defense (DoD), analysts spend enormous amounts of time sifting through these data to detect events of interest, categorize them, and report them through the appropriate channels. Analysts are well-trained in their ability to sift through data, however, the amount of analysts available to perform this work is limited. The volume of the data is increasing rapidly, and as this increase continues, it will be more difficult for analysts to find the bandwidth to support this activity. As a result of this limited bandwidth and lack of equivalently increasing number of personnel, the DoD community will have to prioritize which data to analyze. This will inevitably lead to unintentionally missing significant events. As this trend continues, how can the DoD improve this process and alleviate the workload? One solution is to employ machine learning; more specifically, deep learning to the imagery to perform change detection as well as object detection and localization such that further methods for drawing higher-level insights on Patterns of Life can be enabled. Employing these methods could ensure that all of the data gathered could be analyzed without requiring more analysts. The paper will describe the background associated with Patterns of Life analysis and discuss in detail the development of a modified U-Net architecture adapted to do change detection for military applications with overhead imagery. The described architecture will show the DoD community a viable approach for dealing with the problem of scalability that comes with collecting increasing amounts of data. Additionally, the paper will explain how the method was tested with publicly accessible satellite imagery datasets, and finally, describe conclusions about the work in terms of warfighter applicability.

Machine Learning at the Edge: UAV Automatic Takeoff and Landing

Anastacia MacAllister, Ph.D., Rey Nicolas, Alicja Kwasniewska

22127

Artificial Intelligence (AI) and Machine Learning (ML) are an increasing area of emphasis for the Department of Defense (DoD). In their 2022 budget the Pentagon requested $4.3 billion dollars for AI/ML related efforts, an over 50% jump in a two-year span. Unfortunately, much of the driving technology is being developed for commercial applications due to the relatively small size and challenges associated with the defense market. Common commercial assumptions like ample compute power, internet connectivity, and stable power are not valid in DoD applications due to deployment in what is referred to as the edge on low size, weight, and power (SWaP) platforms. Edge AI/ML refers to the process of processing data and running algorithms on the deployed device rather centrally. This concept allows AI/ML to run without connectivity, an important feature for military platforms that can experience degraded communication. In addition, DoD edge computing often happens in low SWaP environments due to mission and cost requirements. This can be challenging for commercially developed technology that often is designed to live in large data centers with access to ample compute resources. As a result, to make AI/ML technology deployable and tactically relevant, edge computing and low SWaP deployment problems need to be addressed.

This paper describes the process of deploying AI/ML models in low SWaP environments at the edge. Specifically, the paper looks at developing a vision based automatic take off and landing deep learning system for an unmanned aerial vehicle (UAV). The paper details the model development and optimization process for low SWaP deployment. In addition, the paper covers testing of the model using different deployment optimization strategies and the trade-offs associated with each. Ultimately, the paper will provide the community with an example of how to address a pressing problem associated with deploying AI/ML for military applications.

The AI Director: From Document to Documentary

David Noever, Joseph Regian

22173

For gaming, training, and video directing, the high cost and intensive labor requirements limit the transformation of the initial abstract concept to the final product either as a film or as interactive software. This paper investigates the steps required to translate rough instructions into instructional materials. Where possible, we insert machine learning to automate those transformative steps from script to movie. The DoD repositories of archived training manuals, reports, and lessons learned include a vast and varied mixture of step-wise instructions and industrial-style line drawings. We model the AI input as a human-machine interchange, augmenting the role of human auteur with an automated associate director. The example training builds on a long military tradition in fielding portable kits (e.g., mess kit or first-aid bag), but augmented in our case by the modern AI tools to script a set of original instructions using natural language processing. We apply custom text-to-speech tools to dub audio tracks and narrate the required assembly steps. Using the visually creative elements of generative adversarial networks, we complete the required visual representations from the initial script as single images, then animate reels and entire vignettes for video story-telling. To evaluate the output quality, we build a complex multi-stage set of instructions for the use case of fielding an optical microscope with both virtual modeling and real test scenarios. The original training material walks a soldier or medic through how to upgrade from a Vietnam-era field microscope (Model 3050) to the Lego Microscope as first developed by UC San Francisco but later enhanced by IBM and biophysicists at the Universities of Göttingen. We chose this case study to compare an AI-inspired modular approach and to complete complex human tasks that offered real-world building blocks (Legos) with readily available designs.

Correlated Histogram Clustering

Randal Allen, Ph.D., Brice Brosig

22184

Many popular clustering algorithms require a priori knowledge of the number of clusters, e.g., k-means and spectral clustering. This requires you to already know some things about the data (which we often don't) or that you have to try to learn things about that data which becomes intractable for large, unstructured, and high-dimensional data. Nearly all popular clustering algorithms use distance as the metric – though not inherently bad all the time – it can introduce hyperparameters like distance thresholds that again, require a priori knowledge about the data.

This paper introduces Correlated Histogram Clustering (CHC) which requires no a priori knowledge for the number of clusters and assumes nothing about the magnitude of values in any dimension. Designed to handle large, unstructured, high-dimensional, and noisy data, CHC leverages probabilistic techniques to build density estimates rather than using distance metrics. CHC uses the lowland modality algorithm to determine the modes of each dimension and then correlates the modes with points in the original dataset to form a cluster centroid. This cluster centroid may then be used for training, thereby substantially reducing the amount of data needed for supervised learning.

Sorting the significant few data values from the insignificant many in training data using CHC can be used to transform training syllabi by identifying which elements in a syllabus correlate with real skill attainment, and which elements do not accelerate skill attainment. Additional benefits of applying CHC to large, unstructured, high-dimensional, noisy data include dimension reduction and an understanding of the modal nature of the data. In one supervised learning classification application, twenty-seven features were reduced to only three, an 89% reduction of the dataset.

Probabilistic Analysis for Structuring an Effective Defense against Adversarial Attacks

Nickolas Vlahopoulos, Syed Mohammad, Ph.D., Geng Zhang, Sungmin Lee

22203

The Department of Homeland Security has a strong interest in utilizing innovative simulations for planning the distribution of resources in order to prevent and defeat attacks from adversarial actions. In this paper a creative Attack-Defense Tree (ADTree) capability is presented. It allows an analyst to define any adversarial/defending scenario and conduct probabilistic computations for determining the effectiveness of the defensive structure. A dedicated graphical user interface (GUI) makes it easy to define adversarial attackers, their attributes and the associated capability levels, their coordinated actions, their objectives, and all alternative paths for reaching their objectives. The defensive structure is also defined in the GUI. It includes all defense elements that are deployed along the potential paths of the attackers, their attributes and the associated capability levels, and how the adversarial attributes of the attackers compete against the defense capabilities of each element. Coordination of resources among defense elements and the use of sensors and other detection capabilities as part of the defense infrastructure is defined in the GUI. The ADTree conducts the probabilistic computations while considering all possible ways that each threat can accomplish its objectives and computes the probability of success of the threats. The match-up between the capabilities and strengths of the adversaries' vs the defense is considered in the computations at every step along each path that leads an adversary to an objective. The detection of a threat is also accounted in the analysis. The innovative theoretical elements of the probabilistic computations that provide flexibility for modeling any scenario of interest are presented and several examples are discussed. The latter include an active shooter at a school, a cybersecurity example, and a border patrol case. The examples present the utility of the ADTree in determining the most efficient approaches for hardening a defense.

Translating AR/VR Research into Useable Information for Non-researchers

James Belanich, Ph.D., Frank Moses, Ph.D., Emily Fedele, Brian Flowers, Susannah Hoch, Wink Bennett, Ph.D.

22229

Numerous meta-analyses suggest that Augmented Reality (AR) and Virtual Reality (VR) technologies can be effective for training and performance enhancement. However, the broad assertion of AR/VR effectiveness is overly simplistic and clouds important factors influencing the generalizability of findings. To clarify how to use the AR/VR findings, we conducted an initial review of the research literature, organized and simplified knowledge scattered across effectiveness studies, and developed a training effectiveness framework to organize and explain them. The initial set of studies reviewed were conducted by those in disparate fields including computer scientists and engineers who focused on technology, educators who focused on instructional methods, and domain specialists (e.g., medical, military, and construction) who focused on implementations in their disciplines. Our initial review found many clarity issues, such as lack of: descriptions of users' task experience (26% of studies), AR/VR technology experience (28%), and performance measures (29%). In addition, we found inconsistent use of terms, identification of a system without specifying features used, and limited descriptions of task trained. Based on this initial review and discussion sessions with AR/VR professionals, we developed a practitioner-oriented framework to help systematize and bring clarity to the often discrepant research findings. The framework features a common language with five categories. The categories are: What is the technology? How is it used? Who are the users? What is the performance or training domain? What effectiveness was found? Using this framework, we are populating an online knowledge base that can be queried with specific characteristics that help tease apart the evidence of effectiveness for AR/VR technologies in a nuanced and systematic way. We summarized each study in the knowledge base using the framework's standardized structure to make the empirical findings more coherent, and to help practitioners better translate the research findings into practice.

The Use of AI/ML to Replicate Threat Behavior for Nonlinear Simulation

Charles Etheredge, William Marx, Kyle Russell, Timothy Hill, Daron Drown

22230

The development of models that replicate complex, non-linear, adaptive, constructive threats poses challenges for training simulation developers. As threats to our nation's defensive systems mature, our ability to characterize and model them needs to improve so that we are not outmatched.

This paper reports on the progress of our Research and Development (R&D) implementing interdisciplinary methods for Big Data analytics, Artificial Intelligence (AI), and Machine Learning (ML) to capture, characterize, and replicate red player/threat behaviors. We used a progressively complex development and testing framework. First, we selected a pathfinder application that was sufficiently complex to require game play and adaptive behavior on both sides. The paper will discuss our implementation of a Mini-max algorithm, a recursive algorithm used in decision-making, and our rationale for using this algorithm to benchmark the progress of our ML algorithms, with comparisons to others' implementations cited in relevant research. As we tested our AI against humans, we tailored several AI parameters to make the system easier or more challenging as a human opponent. To capture human behaviors, we record all moves made by both sides, per game, and per event. An event is defined as a discrete period, usually 3 days, where multiple human players' moves are captured.

Our solution to this challenge required us to train our ML algorithms on the individual and collective behavior of human players at an event. The paper will describe how we have been able to replicate human player/threat behavior for three events, with references to others' implementation in scientific literature. The paper will also describe logical extensions to problems of interest to the Department of Defense, Department of Homeland Security, and cyber security. Those domains include human, machine, and cyber players and opponents whose behavior can be replicated using our AI/ML methods.

Large-Scale Pattern of Life Simulation for Real Time Applications

Nick Giannias, Evan Harris, CMSP, Stijn Herfst, Roland Geraerts, Alistair Thorpe, Aidan Hobson Sayers

22235

A confluence of technologies has made the simulation of large-scale pattern of life possible to support real time applications. Ubiquitous cloud computing, new generation application scalability frameworks, advanced crowd modelling software, geospatial data production tools and high fidelity/high performance visualization all contribute to the capability not only to simulate city and country sized populations but also do it in real time to support visual simulation applications.

Our work focuses on simulating population mobility, specifically pedestrian movement, as they go about their daily lives but also with the ability to interject events that would cause visible changes in their behaviour. Our objective is to go beyond simple clutter with performance and fidelity requirements that includes (i) a persistent population size of 100K – 1M+ independent agents and a minimum crowd size of 50K (ii) obeyance of walking areas and avoidance of other moving entities and (iii) a simultaneous visualization of the entire population and a game quality street level visualization of any area in the city. We believe this capability can contribute to any simulation and training application that can benefit from a realistically populated city, especially one that may require human interactivity. Specific examples include emergency evacuation scenarios, large crowd protests and military operations in urban terrain.

This paper begins by reviewing the significant existing work in this field that has inspired our methodology. It then reports on the design, implementation and integration of the various components that allowed us to achieve our overall objectives. Finally, it discusses the lessons learned and also looks to the future in this rapidly advancing field.

Trends in Machine Learning for Adaptive Automated Forces

Austin Starken, Sean Mondesire, Bruce Caulkins, Annie Wu

22243

Critical to Army readiness, simulation-based training offers a cost- and time-effective way to keep personnel well-versed in their roles, responsibilities, tactics, and operations. Simulation supported exercises currently require long planning timelines and significant facility and personnel resources. Though semi-automated military simulations provide basic behavioral artificial intelligence to assist in fulfilling participant roles, they still require human simulation operators to control friendly and opposing forces. Often these exercise support simulation operators come directly from the intended training audience assigning Soldiers role-playing duties versus training with their organization. Simulations are intended to make the training process simple and repeatable. However, the current overhead of simulation supported training events overwhelm units and prevent them from getting quality training repetitions needed to gain proficiency. One method of reducing this overhead is through machine learning trained, adaptive opposition forces (OPFOR).

Recent machine learning advancements, such as Deep Mind's AlphaZero and AlphaStar, produced computerized agents capable of defeating professional human players in complex strategy games in real-time. Complex strategy games create an environment consisting of multiple agents capable of making their own decisions while sharing a common goal. Furthermore, these multi-agent platforms typically present imperfect information for the agents due to fog of war, contain large state–spaces, and require three-dimensional terrain navigation. These feats help support the idea that machine learning may be the key to developing adaptive OPFOR in military constructive simulations.

This paper surveys the existing literature in the use of machine learning for automated OPFOR decision making, plan classification, and agent coordination. Further, this paper reviews current advancements in temporal-adaptation to analyze how quickly machine learning agents can adapt to a change in their environment. This analysis serves as a starting point for any future research in the current capabilities and limitations of developing adaptive OPFOR in support of military constructive simulations.

Novel Method for Modular Integration of Tactile Input Devices into Portable AR/VR Training Systems

Jad Meouchy, Suzanne Borders

22281

The training and simulation industry has made tremendous progress with software virtualization of physical environments, but the integration of tactile input/output remains nascient. While there are many ways to connect wired peripherals to desktop computers, there are few solutions for fully mobile applications. Connecting physical devices through USB or BLE to battery-powered AR/VR headsets is technically challenging as these headsets run mobile operating systems like Android or Windows Holographic that do not possess drivers or even ports for connecting external hardware. Further, the precise communications protocols that these devices use are rarely, if ever, documented.

This paper presents a recently patented engineering technique and solution for rapidly integrating BLE/USB devices into mobile platforms. When confronted with a known or unknown device, the process begins by leveraging open source tools to discover and analyze the device's emitted messages. From this log, a human-readable configuration file is constructed that contains semantic descriptions and measured values in a specific shareable format. Finally, configurations are fed into a lightweight and cross-plaform device driver that proxies raw wired and wireless packets including the oft-overlooked HID protocol. The end result is mobile support for a wide array of wearable and mountable input devices, and a manner for adding new devices without coding.

Immersive training applications will be empowered to connect wearables like smartwatches and fitness bands, mountables like commercial flight simulator controllers and smart home panels, and countless other new and old IoT devices. As the communication is inherently bidirectional, integrations provide for both user sensor input to the app and tactile feedback from the app. General compatibility with input devices will allow the next generation of immersive training apps to be more realistic, versatile, and transportable for a variety of mission needs.

Innovation, It's in VR: How the Spanish Military Health School is Revolutionizing Workforce Training with VR Immersive Rooms

David Moreno, Maria Madarieta, Valentín Gonzalez Alonso, Antonio del Real Colomo

22282

Workforce training continues to be a key area to help achieve some of the main targeted goals for the military and other high-risk industries: Implement the most significant savings opportunities in the most efficient manner possible.

The demand of more realistic and innovative ways for training is increasing, where safety and knowledge retention are becoming even more important elements in today's social and economic environment. For instance, the possibility to train several units based in different locations but in the same large-scale virtual environment. This improves the individual, team and unit-level performance in emergency and conflict situations, but also reduces the investment in physical replicas and even the expenses of bringing the units together to one location for training.

Virtual Reality is definitely establishing itself as the standard for training across industries. The example the abstract will be based is The Spanish Ministry of Defense and how they are shaping the training processes modernization of the medical staff of the Military Health Corps in up to three highly complex environments related to (Chemical, biological, radiological, nuclear) CBRN protocols through a warehouse scale multi-user VR simulator. The key differentiator is that they are introducing a revolutionary concept based on Virtual Reality Immersive Rooms.

Last year finalist paper (I/ITSEC 2021 Paper No. 21142) will offer evidence of the results as well as learning outcomes and lessons learned with the Spanish ministry of defense as a best practice.

Automating Video After Action Reviews for Military Medical Training Exercises

Nicholas Walczak, Brian VanVoorst, Elias Noyes, Mark Mazzeo, Jack Norfleet, Ph.D.

22292

Video represents a powerful tool for enabling high quality debriefs or after action reviews (AARs), however there are many challenges to utilizing video for debriefing. One key challenge is the necessary effort to find the specific time (bookmarks) in which important activities occur (i.e.; highlights). To alleviate these issues, we have developed a system for recording, ingesting, and automatically bookmarking video from person-worn cameras during military medical training exercises. By utilizing person-worn cameras, we are able to eliminate the requirement of having a separate videographer. This system was used at Joint Base Lewis-McChord to record exercises as part of a recent study. Our system was able to document all of the events that took place without any loss of data. Furthermore, using the algorithms we developed the system was able to bookmark key medical activities such as when tourniquet application, gunshot wound treatment, and needle chest decompression where performed with an accuracy of X% (97% for tourniquets, Y% for chest decompression, and Z% for gunshot wound treatment; some of these numbers are still being computed and will be ready for the paper review but aren't currently ready). This video was later presented to instructors where it provided sufficient detail to accurately assess performance. On average, the video and associated bookmarks were available for review within X:XX minutes of turning in the camera, even though the average length of the video was XX:XX minutes (a processing speed that is X% of real-time; of these numbers are still being computed and will be ready for the paper review but aren't currently ready). In addition, advanced features of the system are able to provide assessment metrics, such as estimated time to complete a tourniquet application.

An Approach and Three-Dimension Taxonomy for Adaptive User Interfaces

Spencer Kohn, Robert Jacobs, Athena Johnson, Ewart de Visser

22304

Adaptive user interfaces change according to the needs of each user and context by conforming their appearance, interactions, and level of automation to the operator's cognitive state. Mental workload has been one of the

most popular aspects of cognition to adapt, due to the potential to reduce stress and improve performance. Recent improvements in computing and physiological measurement have expanded possibilities for cognitive state measurement beyond workload, and now include trust and situational awareness as potential candidates for interface adaptation. However, capturing and adapting three dimensions exponentially increases complexity, and makes it difficult to adapt specific dimensions without disrupting others.

This paper presents an integrated approach for conceptualizing the combined operator cognitive state, a set of priorities for adaptation, and a taxonomy for factors that can be adapted. The operators cognitive state is conceptualized as a three-dimensional array, or tensor, with an ideal state of balanced workload, calibrated trust, and high situational awareness. This tensor permits demonstration of which operator states must be adapted first, and how each adaptation affects other states. A taxonomy of candidate adaptation factors is presented within this context, enabling future designers to explore and implement this methodology within their own future work.

ORB-Recon: Live 3D Reconstruction from Wearable Video

David Ramirez

22330

Augmented reality is a key technology which promises to change the future of warfare. Hybrid AR military training will enable outdoor engagements with long distance enemies, both real and simulated. For live military training over a large area, a 3D model of the world must be maintained based on sensor observations. To proliferate AR technology, 3D reconstruction algorithms must utilize the low cost and pervasiveness of video camera sensors, from both overhead and soldier-level perspectives. Mapping speed and 3D quality must be balanced to enable live hybrid training in dynamic environments.

Given these requirements, we present a live 3D reconstruction pipeline for large scale mapping for military applications given only live video. Our method, ORB-Recon, uses ORB (Oriented FAST and Rotated BRIEF) feature points to reconstruct a 3D model of the world in real-time, while tracking the location of dynamic objects such as humans and vehicles. ORB-Recon is derived from and published open source and free to use by all. To evaluate the challenges of 3D reconstruction quantitatively, we utilize the autonomous driving academic benchmarks KITTI and KITTI-360, minimizing the error in point cloud 3D placement compared to these baselines. We measure 3D reconstruction performance to common structure from motion, visual-SLAM, and photogrammetry techniques. ORB-Recon outperforms other state of the art techniques when combining speed and reconstruction quality metrics. We qualitatively stress-test against two new benchmarks: 1. Hiking the Grand Canyon while updating a 3D model at both a local and massive scale; 2. Military-simulation paintball from multiple live perspectives. Finally, we investigate pulling 3D terrain elevation maps from One World Terrain, as well as pushing back live updates from soldier-level perspectives.

High-Level Orders for Intelligent Agents to Rapidly Generate a Realistic Battlespace

Brian Mills, Robert Ducharme

22351

Today the defense industry, the warfighter, and government leaders are all looking to modeling and simulation to solve new technology and security challenges such as a) the creation of large-scale battlespaces to test new technologies and concepts b) create the vast amounts of data required to train machine learning models c) provide new ways to inform decision makers with campaign-level simulation. Unfortunately, creating complex, multi-domain simulations is a time-consuming and expensive endeavor. At CAE, we are working to solve these issues by developing a high-level, natural language framework for rapidly generating large and complex, multi-domain battlespaces and communicating with intelligent agents within simulations. A framework will be introduced where intuitive commands can be given to a simulation to generate large formations of entities as well as issue orders and commands to the formations. A system of collaborative intelligent agents then interprets these orders as mission objectives, which are then further broken down into country, unit and platform specific tactics that can be applied to the specific scenario to get a desired outcome.

Enhancing Wargaming Fidelity with Communication Modeling Services

Ha Duong, Jeffrey Weaver

22353

As outlined in the 38th Marine Corps Commandant's Planning Guidance (CPG) 2019, wargaming is one of strategic focuses that will emphasize on the effective integration of professional wargaming in force design, education, and training. Following this guidance, US Marine Corp is looking for the next-generation wargaming that will embrace various types of wargaming, from concept development, capability development and analysis to wargaming for operational decisions and plans, training and education. As each of those wargaming types involves human players or actors making decisions in constructive contest environment and then dealing with the consequences of their actions, communications and networks to contain, extract, and disseminate time-sensitive, mission-relevant information have become a critical part of wargaming, requiring high fidelity models with realistic cyber, communications and networking.

Our previous work presented an innovative and unique prototype to incorporate high fidelity cyber, communications and networking simulation into a wargaming environment. In this paper, we will look at enhancement from different angle where we propose an architecture to provide communication modeling services during different phases of a wargame (objective formulation, design, develop, rehearsal, execute and post-game analysis) and for different types of wargaming. The architecture includes a wide range of communication modeling service from RF layer (reachability, link quality) to network planning, optimization and performance assessment. It can also emulate specific mission data flow in realistic network condition and cyber contest environment to better assess mission outcome. Its design is flexible, allowing different types of interfaces to communicate with other wargaming tools. REST API is used for quick response to a request from a wargaming tool. Interactive GUI interface allows a wargamer to be involved in the process of modeling communication service. Realtime interface allows exchanging data between CMS and other wargaming tool in real time either directly (e.g., DIS) or via middleware (e.g., TENA).

Improve Aircraft Maintenance Sortie Production Rates with Mixed Reality and Artificial Intelligence Assistance in Maintenance Processes

Dane Stevenson

22357

The average age of USAF aircraft is 29 years, and this aging fleet requires skilled maintenance personnel to perform constant care to generate airpower. The Air Force employed the use of virtual and augmented reality technology to aid in developing aircraft maintenance personnel as well as to supplement established training methods. The application of augmented and virtual realities has reduced the time needed for classroom instruction during maintenance initial skills training without sacrificing the quality of education. The next step is to develop a system and processes that use extended reality assisted with artificial intelligence for use on the flight line. Various industries have developed augmented reality capabilities that can be used by the Air Force to provide access to technical orders in a hands-free medium. Mixed reality will also open opportunities for multimedia walk-through instructions that include video teleconference support within a headset. Artificial intelligence has the potential to assist a maintainer through mixed reality by providing predictive maintenance instruction while informing quality assurance processes in near real time. Artificial intelligence could recognize tasks at hand to help recall instructions and record accomplished tasks. Theoretical applications like this could free the cognitive load of individuals by automating the need to record information and recall reference material.

The scale of equipment needed to accomplish this AI assisted vision is not developed yet but several industry efforts with further development could enhance aircraft maintenance operations. This paper will compare current augmented reality technologies being employed by the USAF, those in development in complementary industries, and look for solutions that improve sortie production rates as well as their first-pass quality work. This cost benefit analysis will be measuring the time saved on process due to use of augmented reality assisted with artificial intelligence versus already established procedures.

Achieving Intelligent Behavior in Multi-Domain Electromagnetic Warfare Environments Through Neural Network-Informed Search and Self-Play

Michael Ganger, Gerardo Leal

22372

Effective personnel training and sub-system testing in synthetic warfare environments has achieved incredible levels of realism and fidelity in physics and human-machine interface. However, progress has lagged in constructive behaviors—specifically, in planning and decision-making over long time horizons—with simulations still relying on scripted or rules-based behavior models. In contrast, we hypothesize that "intelligent" constructive behaviors can be realized automatically through maximization of long-term rewards. To test this, we design an implicit approach using Neural Network informed search, trained through self-play without input from a human expert, to estimate the best action for an entity and expected outcome of a scenario. We demonstrate emergent "intelligent" human-level behavior in multi-domain environments with electromagnetic actions and non-trivial collections of entities, with applications to adversarial training simulations.

Perspectives for the Future: Considerations for UAM Aircraft Information Requirements

Maria Chaparro Osman, Maureen Namukasa, Kendall Carmody, Bhoomin Chauhan, Gervauhgn Berkel, Meredith Carroll, Ph.D.

22378

Advanced air mobility (AAM) is a novel concept of air transportation using electric vertical take-off and landing (eVTOL) aircraft to move passengers and cargo between urban, suburban, and interregional transportation networks. The AAM domain is introducing new pilot interfaces aimed to facilitate reduction in pilot training and the eventual transfer of pilot-in-command responsibility to automated systems on the aircraft. To achieve this, AAM is designing for simplified vehicle operations (SVO), which focus on the application of automation coupled with human factors best practices and approaches (General Aviation Manufacturers Association, 2019). The SVO concept aims to ensure seamless coordination and execution of both independent and joint pilot and automation functions eventually reducing the time and training required for new pilots to fly an aircraft. This aligns with the current focus in the military to accelerate training and reduce the time required to complete training.

A market survey was conducted to identify leading eVTOL aircraft configurations and trends in SVO pilot interfaces. Common trends identified included large displays, integration of flight information such as speed, altitude, heading, climb and descent rate, flight path, battery power information, origin and destination of the flight, weather information, aircraft range and location, tilt information, and rotation per minute (RPM). Proposed pilot interfaces range in their level of landing precision information, the number of displays, checklist presentation, and how battery information is presented. Interviews were then conducted with civilian and military helicopter pilots, military UAS operators, and fixed-wing electric aircraft pilots to understand the major differences between traditional and SVO pilot interfaces and to obtain expert pilot reactions to SVO pilot interfaces, including what they foresee as the benefits and challenges. Findings from the market and interview studies will be presented, including relevancy to the design of future pilot interfaces for both commercial and military applications.

Building a Cloud-Native Toolset for Flexible, Continuous, Automated Simulation-Based Testing

Jeremy Loomis, Alex Matthews

22380

The discipline of software testing is changing to align with the automated processes of Agile DevSecOps. Automated testing is executed by running test scripts or scenarios against the System Under Test (SUT) without human intervention. With many types of software (such as C4ISR applications), a challenging aspect of this testing is generating synthetic data and activity to stimulate the SUT.

Modeling and simulation (M&S) can help by providing representative test data from synthetic actors in a synthetic environment. Building on current M&S tools, a Simulation-Based Testing (SBT) approach can inject synthetic test data into a Continuous Integration / Continuous Deployment (CI/CD) pipeline. SBT requires two interconnected elements: M&S-as-a-Service (MSaaS) services and an Automation & Orchestration ecosystem.

This paper describes our Simulation And DevOps Integration Environment (SADIE) project, which built a prototype SBT toolset using existing COTS/GOTS software. SADIE is a cloud-native (deployable to any Kubernetes cluster) modular toolset that works with any SUT and CI/CD toolchain. It provides continuous automated testing based on a flexible architecture (users can author scenarios, jobs, and pipelines).

MSaaS is implemented with cloud-hosted microservices aligned with the NATO MSaaS Reference Architecture. A Scenario Editor is used to author relevant scenarios and a Scenario Repository stores and catalogs versioned scenarios. SADIE wraps existing Simulation Engines (STK, AFSIM, NGTS, OneSAF) into Simulation Service microservices.

The Automation & Orchestration ecosystem centers on the SBT Job Manager which coordinates execution of SBT jobs. The Job Manager connects Simulation Service Adapters (for configuration and control of Simulation Services) to SUT Adapters (to translate data into the required formats/schema and protocols for injection). It can be controlled from any build orchestrator (e.g., Jenkins) using a REST API.

We conclude with an end-to-end use case showing how SBT can use M&S to provide CI/CD quality gates based on regression testing results.

Enhancing Warfighter Training and Performance using Motion Tape Elastic Fabric Sensors

Kenneth Loh, Ph.D., Shih-Chao Huang, Yun-An Lin

22381

Physical, tactical, and field training are critical for improving warfighter physical performance and capabilities. Exercises and training events are typically supervised; however, group/team training lacks personalized supervision, which is even more difficult during field events and in forward deployed situations. While technologies such as optical motion capture (mocap) can capture detailed biomechanics, they are most conveniently used in indoor laboratory settings or in a pre-staged outdoor area. Commercial wearable sensors are readily available, but the data typically correspond to a discrete bodily location and only provide limited information about whether someone is moving, as opposed to how movements are being performed. To fill this gap, a self-adhesive, elastic fabric, nanocomposite skin-strain sensor was developed, tested in controlled environments, and validated through human subject studies. It was found that "Motion Tape" sensors were not only able to measure skin-strains during functional movements, but its measurements were also correlated with how muscles engage. In this study, Motion Tapes were worn at major joints and muscle groups, and subjects performed exercises that simulated military training activities. Mocap measurements were also obtained to acquire baseline biomechanical movement data. Individuals (civilians) were first asked to perform a functional task, before being asked to repeat the task after specific instructions that targeted improved performance. Then, a neural network was implemented and trained to classify movement sequences that resulted in positive versus negative task outcomes. The remaining datasets that were not used for training were used for validation. Furthermore, the Motion Tape datasets that led to positive outcomes were further analyzed to reveal the primary movement and muscle engagement schemes that resulted in higher performance. The vision is that such "Warfighter Digital Twins" can be used for assessing the physical performance, health, and capabilities development of military service members.

Application of Artificial Intelligence for Dynamic Military Information Prioritization

Jennifer M. Riley, Ph.D., Timothy Whalen, Audrey Zlatkin

22394

Joint All-Domain Command and Control (JADC2) is an integrated command and control (C2) concept of the Department of Defense (DOD) to connect sensors from all services—Air Force, Army, Marine Corps, Navy, and Space Force—into a single network. This shared tactical network aims to effectively support joint intelligence, course of action development, and decision making in conflicts that may require decisions within seconds and minutes as compared to hours and days. Such connectivity and flexibility is likely to

result in changes to existing C2 architecture, and it is expected to produce massive amounts of data from the multitude of sensor technologies and human intelligence sources across services. For effective decision-making in JADC2, commanders will require specific information relevant to their roles and commander-critical information requirements (CCIRs). High information load, time sensitivity, and delayed, intermittent and low-bandwidth (DIL) environments will benefit from advanced data analysis technologies. The Military Information Superiority Technology (MISTec) is a set of AI algorithms enabling the right data to be routed to the right commander at the right time, supporting JADC2 goals to enable better decisions through AI. Given mission CCIRs and other operational parameters, MISTec derives insights on a commander's dynamic information priorities. From there, incoming data from multimodal sources are analyzed through natural language processing-powered AI to identify individualized priorities for each incoming datapoint. A dynamic messaging priority queue ensures data is optimally routed to individuals, accounting for potentially changing channel bandwidth. Commander feedback to the system facilitates recomputing priorities and ongoing model refinement and personalization. This paper will discuss the development of the AI prioritization engine, how outputs can increase situation awareness in military C2, and how the AI engine can be expanded in future to increase utility to the operational community.

Improving Measurement of Trust Dynamics in Human-Agent Teams

Cherrise Ficke, Kendall Carmody, Daniel Nguyen, Isabella Piasecki, Arianna Addis, Mohammed Akib, Amanda Thayer, Ph.D., Jessica Wildman, Meredith Carroll, Ph.D.

22436

Key to studying and assessing trust in human agent teams (HATs) is the ability to measure it. The predominant approach to assessing team emergent states and trust, more specifically, has been through self-report survey methodologies. However, self-reported trust measures suffer from several limitations including confounding with cognitive biases and social desirability (e.g. Arnold & Feldman, 1981; Taylor, 1961), inaccuracies due to retrospective assessments of abstract concepts (Podsakoff & Organ, 1986), assessment of trust as a static state rather than a dynamic process of emergence (Kozlowski, 2015), and the impracticality of asking members to pause activities to complete a survey. There is a clear need for innovative approaches to better capture trust, for both research and applied purposes. Recently, researchers have recommended and begun transitioning toward unobtrusive measurement methodologies such as physiological measures, event-based behavioral assessments, and language/communication (Azevedo-Sa et al., 2020; Hill, White, & Wallace, 2014; Marathe, Brewer, Kellihan, & Chaefer, 2020; Waldman, Wang, Stikic, Berka, & Korszen, 2015). Psychological measures, including subjective measures, have been correlated with more objective, unobtrusive measures of trust in HATs (Khalid, Helander, & Lin, 2021). For instance, physiological measures such as voice tone and pitch, facial expressions, heart rate, heart rate variability, and electrodermal activity have been shown to indicate trust (Khalid, Helander, & Lin, 2021; Schaefer et al., 2021). Furthermore, behavioral measures such as posture, eye fixations, allocating tasks to the autonomous agent, and manually controlling an agent have also been shown to correlate with trust (Schaefer et al., 2021; Khalid, Helander, & Lin, 2021). This paper will present an integrative review of the literature in this field and propose a theoretically-grounded, Unobtrusive Measurement Framework of Trust Dynamics in HATs that will more accurately, effectively, and practically capture trust in HATs than traditional measurement approaches.

Reducing Image Generator Footprint with Virtualization

Matt Moy

22438

Today's high-fidelity training systems are unable to be efficiently deployed at the point of need due to the size, weight, and power of the equipment that is required. There are limitations with how much the form factor of a system can be reduced, particularly with the slow but steady rise in power requirements on many of the CPU and GPU architectures over the last several years. A new approach is necessary to reduce the footprint of these compute resources.

In this paper we will demonstrate how we were able to reduce the footprint of our image generator systems by 50% using virtualization. This approach brings with it a unique set of challenges. If virtualized using the same approach as a typical server, challenges relating to rendering performance, hardware support, user perception, and network latency are inevitable. These challenges must be addressed to ensure the same quality of delivery with virtualization.

This paper will outline an approach to optimize virtual machines for real-time rendering and provide a testing methodology to verify that they can provide the same experience as their physical counterparts.

This approach includes:

1. Identification of the components for the complete virtualized solution
2. A comparison of a physical versus virtualized IG
3. Measuring average framerate, latency, and utilization, as well as a user's performance completing a repeatable task within the simulation, to verify that virtualization does not have a negative impact on delivery
4. Example use cases that both support and exclude virtualization

The methodology put forth in this paper and supported by the aggregated data points will provide the audience with an option for delivering high quality immersive training without the prohibitive footprint required by current solutions.

Hardware Optimization for Immersive Simulation & Photogrammetric Environment Generation

Jonathan Hawes, Karl Rosenberger

22450

Civilian and Department of Defense (DoD) organizations are leveraging immersive simulation to create a digital twin of the world. This effort to maximize training and capability invokes difficulties when used in the field due to the processing power necessary to reconstruct photogrammetric environments in short suspense. Edge processing typically overlooks two critical areas (1) the hardware best suited to accomplish the task and (2) the most advantageous strategy for integration between the processing system and the software which will power the experience. With optimization in these areas, significant decreases in processing time can be achieved while decreasing the size, weight, and power consumption (SWaP) of the system. This allows for man-portable systems which can be employed directly with the user for training and operational use.

This paper will address the issues stated above by sourcing firsthand data through hardware and photogrammetric software processing benchmarks across three system configurations; multi-socket single node, single socket dual node, and single socket quad node. This data will then be aggregated into the developmental foundation for a new system topology which will offer server grade reconstruction speeds in a workstation form factor. This system will showcase the effects of hardware optimization through decreased processing times, weight, power consumption, and heat generation. A real-world scenario will illustrate the mission-critical system performance and its potential infusion into the One World Terrain ecosystem. Finally, the real-world benefit of focusing on these key components in simulation-based systems for training will be explained along with courses of action for implementation by warfighters at the edge. Converging the advancements in software architecture with the evolution of central processing units (CPU) and graphics processing units (GPU), predicted by Moore's Law, we will set the stage for the next epoch of photogrammetric systems and software.

Automated 3D Terrain Generation at Global Scale Based on Satellite Imagery and Cloud Computing

Arno Hollosi, Thomas Menzel-Berger, Hannes Walter, Daniel Lahm

22454

Providing a photorealistic, geo-typical, geo-referenced, high-performant and updated, 3D digital terrain model of the entire globe has been impossible until now. The reasons are manifold: any manual approach is much too slow, automated methods are lacking regional specific aspects, the amount of satellite input imagery data and necessary processing power for automated methods is just too massive or client-side rendering of photogrammetric models is slow.

For a flight simulation computer game introduced in 2020 our team developed a massively scalable, end-to-end cloud-computing based geospatial platform extracting terrain and infrastructure attributes from a current global satellite

imagery data set and transforming this into a WGS84 georeferenced, geo-typical, photo-realistic, and semantically defined 3D digital twin of earth's infrastructure, capable of being streamed or stored entirely offline.

The technology consists of advanced AI/ML computer vision algorithms and geospatial analysis tools that process satellite and aerial imagery (including RGB, Infrared and LiDAR point clouds) to detect and extract features in those images: terrain, biomes, buildings, roads, vegetation, water bodies, and more. This architecture enabled to process building footprints for the whole inhabited surface of the globe every 72 hours for updates (approximately 11,600 km2 / minute).

To deliver the accurate reconstruction of approximately 1.4 billion buildings and structures covering the surface of the planet (~ 140 million km2) we developed a highly parallelized and resilient cloud architecture that decomposes multiple petabytes of imagery into tiles and processes them across hundreds of CPU and GPU compute nodes in the cloud. The procedural definition of building defines every single building in a unique, geo-typical, photorealistic, yet highly performant way.

Currently the platform is getting adapted for professional image generators, flight simulators and cases such a pilot training and sensor simulation. This brings addition challenges like persistent, synchronized, multi-view, multi-client states or material attributes at global scale.

Designing a Rapid Adaptive Content Registry (RACR) for Adaptive Learning

Benjamin Nye, Ph.D., Aditya Jain, Dilan Ramirez, Daniel Auerbach, Mark Core, Ph.D., William Swartout, Ph.D.

22466

Despite meta-analyses showing strong learning gains for adaptive learning, few domain areas are covered by adaptive learning. A key reason for this is a content bottleneck: currently, adaptive systems require highly-trained computer scientists and educational specialists to add new content. To explore this issue, we are researching a pipeline of interactive tools designed for content managers with little or no training to incorporate content into an adaptive learning ecosystem. This Rapid Adaptive Content Registry prototype consists of four components: Adaptive Module Registry for composing a set of learning resources and learning objectives (competencies) in an intuitive content-management UI; Rapid Content Analysis Service which leverages machine learning to analyze web-pages (static or dynamic), PDFs, or short videos to generate metadata tags on competencies, estimated duration, and complexity; Preview and Text Extraction interface to review, test, and manually extract text from resources; and Module Simulator to analyze the ability of the available content to adapt to different simulated student patterns (e.g., struggling learner, learner starting with partial mastery, etc.) This paper outlines the design principles, machine learning performance, and formative usability testing process for this toolkit. For this research, the performance metrics are authoring time, metadata tag quality, deployment reliability (valid content), and personalized pathways (differentiation between different kinds of learners). A comparison of machine learning models leveraging BERT-S to generate competency tags is presented, which indicates that a general model (not tag-specific) is reasonable for cold-start labels. The tool's usefulness is evaluated by comparing results from an adaptive module for virtual counseling registered de-novo through the tool, as compared to the same content composed and tagged by a team of specialists. Strategies and issues for integrating this into an enterprise ecosystem are also discussed. Initial testing indicates useful potential for such a tool, but also raises questions about how specialized tools should integrate with more traditional content management systems.

An Empirical Evaluation of the PERvasive Learning System (PERLS): Perceptions of Impact

Scotty Craig, Wendy Barnard, Dawn Riddle, Ph.D., Laura Milham, Ph.D., Karen Gordon

22468

The PERvasive Learning System (PERLS) is a mobile microlearning platform designed for learning anytime and anywhere, taking advantage of planned and unplanned time during a learner's daily schedule to enhance and reinforce learning. It is a government-owned platform created by Float for the Advanced Distributed Learning Initiative with advice and independent evaluation provided by the Arizona State University Advanced Distributed Learning Partnership Laboratory. The system uses advanced algorithms to provide tailored learning recommendations to personnel based on their characteristics, learning history, training requirements, and context. The PERLS platform has both mobile application frontend and backend content management software. The mobile application includes a recommendation tool, providing the learner with different forms of content, e.g., reading content, videos, flash cards, knowledge checks, and more. While the learner chooses how to navigate through the material, the PERLS platform adapts to the learner's preferences and level of effort. The backend software allows authors to create, attach, curate, and tag these materials, creating a pool of content to be served to the learner. This allows for distributed, self-regulated, context-aware, personalized learning. An empirical evaluation of PERLS to show evidence of the system within authentic training settings by evaluating assessments from soldiers that used PERLS during their class and those only taking a standard class. A total of 441 soldiers taking classes from the Sabalauski Air Assault School at Fort Campbell, KY were recruited. Overall, the perceptions of the system's effectiveness and measured effectiveness were very positive. PERLS with a robust authoring system and algorithms based on learning science techniques has a strong potential for impact.

Peering through the Fog of War

Deanna Franceschini, Song Park, Anne Logie, Manuel Vindiola, Priya Narayanan

22469

Machine learning (ML) based Artificial Intelligence (AI) is revolutionizing many areas of modern life, including translating conversations between different languages, identifying people in pictures, and autonomously driving cars. All these advances have created new, more complex, and challenging tasks where even human execution of these events sometimes falters due to lack of specialized training, lack of attention, information overload, or fatigue. Military commanders from the very earliest days have always been faced with the "fog of war", but in today's digital environment, not only can we begin to see through fog, but we can begin to glimpse the foundational components of that "fog". Similarly, the actions of a Commander in a battlespace are affected by degree of training, attention to detail, and fatigue. Conducting tactical operations within a Multi-Domain Operation (MDO) environment exponentially increases the complexity of a leader's Command and Control (C2) with the inclusion of space, cyber-electromagnetic activities (CEMA), and robotic assets, which are likely to drive the OPTEMPO even higher than in the past. Given the pace of operations, the complexities of the Operational Environment (OE) and the speed at which decisions must be made, sometimes minutes, – the Commander and their staff are simply overwhelmed in trying to assess in a timely matter what information is needed to allow the commander to make the best decision possible. In collaborative work with the Army Research Labs, we have been exploring the application of Deep Reinforcement Learning (DRL) towards generation of automated Decision-Making Assistants. There are many practical uses for such a capability, including exposing novel or optimal Curses of action (COA), identification of timely and unique threat activities that influence friendly plans, and the supervision of autonomous battlefield systems and activities. In this paper we describe the overall approach, describe the project's status, and provide lessons learned.

AI Enabled Maneuver Identification via the Maneuver ID Challenge

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22475

AI has enormous potential to improve Air Force pilot training by providing actionable feedback to pilot trainees on the quality of their maneuvers and enabling instructor-less flying familiarization for early-stage trainees in low-cost simulators. Historically, AI challenges consisting of data, problem descriptions, and example code have been critical to creating AI revolutions. A joint MIT and USAF team (the USAF-MIT AI Accelerator) has developed such an AI challenge using real-world Air Force problems. The Maneuver ID challenge has assembled thousands of virtual reality simulator flight recordings collected by actual Air Force trainee pilots at Pilot Training Next (PTN). This dataset has been publicly released at Maneuver-ID.mit.edu and represents the first

of its kind public release of USAF flight training data. Using this dataset we have applied a variety of AI methods to separate “good” vs “bad” simulator data as well as categorizing and characterizing maneuvers. The algorithms and software are described and are being released as baseline performance examples for others to build upon to enable the AI ecosystem for flight simulator training.

HUMAN PERFORMANCE ANALYSIS AND ENGINEERING

BEST PAPER

Automated Assessment of Team Performance Using Multimodal Bayesian Learning Analytics

Caleb Vatral, Gautam Biswas, Naveeduddin Mohammed, Benjamin Goldberg, Ph.D.

22258

The increased adoption of mixed-reality simulation-based training environments along with the use of multimodal sensing devices has led to a proliferation of participant interaction and behavior data that can be collected while scenarios are executed. Analysis of this rich data using advanced AI and machine learning algorithms makes it possible to create robust multi-dimensional models of individual and team performance that can include psychomotor, cognitive, metacognitive, and affective factors. Moreover, through a multi-dimensional approach one can compute performance metrics within single training instances, as well as across a full course of training scenarios. This provides valuable feedback to trainees and their instructors on their skill levels, proficiency, and progression over time. However, developing objective data-driven performance metrics come with a set of challenges that include data collection and aggregation, pre-processing and alignment, data fusion, and the use of advanced multimodal learning analytics (MMLA) algorithms to compute individual and team performance.

In this work, we present a case study of teams of three to four soldiers training on dismounted battle drills in a mixed reality-training environment. We develop our multimodal computational architecture and demonstrate the use of advanced machine learning based MMLA algorithms to analyze the collected training data that spans video, speech, and simulation logs. We model the progression of the teams of soldiers through the course of multiple training scenarios and show their progression over time on both operationalized domain-specific performance metrics, as well as higher-level cognitive and metacognitive processes., To show how these automated analysis methods can be presented to trainees and instructors to supplement traditional expert feedback, we present the MMLA analysis through the lens of distributed cognition. In addition, we show how results from our analysis methods can be used to provide suggestions for both future training needs and potential improvements to the training environment.

Resident or Virtual: The Impact of Foundational Education Modality on Army Instructor Job Performance Outcomes

Christina Parker, Leonard Momeny, Davin Knolton

22110

The following paper identifies the competency and job task performance frequency of military training organization instructors as well as explains performance outcomes based on foundational instructional modalities. Specifically, is there a difference exhibited in frequency of performance-based competencies as a result of original instructor training being conducted face-to-face compared to virtual environments? In December 2021, a quantitative study highlighted the competency and job task performance frequency of Instructional Systems Specialists (ISSs) within military training organizations. That study indicated that Instructional Design (ID) competencies and ISS position description (PD) job duties specific to the Instructional Systems Design (ISD) or ADDIE process were performed only quarterly or less. A 2020 qualitative study on ID practices in military training organizations suggested that those without the requisite educational backgrounds, those in instructor or 1712 positions, were often performing ADDIE related competencies and tasks in lieu of the ISS. This study seeks to extend a similar assessment to the job performance frequency of instructors within military training organizations, while specifically considering foundational instructional modality. The results of this study in conjunction with the results of the 2021 and 2020 studies provides a more complete view of job performance across training and education personnel specific to the Army Training Enterprise. The authors argue that identification of instructor task performance and differences within learning environments can inform instruction design gaps and considerations for instructor training depending on the educational venue. It can also inform Army Faculty and Staff personnel of design considerations for the CFD-IC in order to improve areas of instructor job performance identified as low performance frequency.

Designing HMI for Mission Assessment of Human-Machine Teaming

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22126

With the emergence of human-machine teaming, human machine interface (HMI) design needs to change the paradigm of how displays are used to eliminate the “fog of war" through increased situational awareness and informed decision-making to improve performance. The modern battlespace is extremely complex with disruptive technologies being integrated into dynamic, sociotechnical environments. With the vast amount of data available today due to the growth of computer power and data analytic techniques, understanding the relevant data and its appropriate use for improving performance is challenging.

This paper describes the application of an ecological design interface approach used to develop real-time HMIs with an automated warfighter readiness assessment. The use case focused on a human-machine team Air Warfare domain with Naval Flight Officers providing command and control to fighter pilots with an artificial intelligent (AI) Agent flying their ownship while pilots were controlling up to four Unmanned Aerial Vehicles performing air-to-air intercepts.

Cognitive engineering models were used to develop computational models of cognitive workload and mission performance. These models were also used as the foundation to design HMI solutions that provide the right data, with the appropriate level of abstraction and navigation mapping for the organization of displays. Instructors and mission commanders have persistent and personalized, human-centered technology capable of quantifying individual and human-machine team performance in a dynamic and distributed environment. A usability test was conducted, and feedback was collected. Initial feedback indicates that this information can be used to select and train warfighters, design HMI, and assist mission controllers in protecting and effectively conducting operations for improved mission effectiveness.

Eye Motion Tracking for Desktop-Based Medical Image Interpretation Training

Chanler Cantor, Matthew Schultz, William Marx, Junjian Huang, Andrew Smith

22171

Previous efforts such as the USAF Pilot Training Next (PTN) initiative have shown the value of Eye Motion Tracking (EMT) in assisting the trainee to more effectively build required skills when learning where and when to look; how to search, detect, and/or recognize patterns; and how long to gaze. Similar complexity to these DOD operator consoles and cockpits can now be found in myriad applications across many market segments. The purpose of this research paper is to demonstrate the extension of potential benefits of obtaining real-time feedback of trainee eye direction and gaze duration to other use-cases beyond military training, in this case medical imagery interpretation. This real-time indicator can allow the trainer to adapt verbal queueing of the trainee to improve knowledge transfer. It can also provide objective verification evidence that the trainee is indeed looking and gazing at the intended locations on the monitor.

This paper reports on joint Research and Development (R&D) activities exploring Eye Motion Tracking (EMT) for training. EMT is popular in professional online gaming, providing amateur e-sport fans a method of

watching precisely where professional players' eyes are looking as they play complex games with data-intensive user interfaces. The authors are currently evaluating the ability of EMT systems to improve radiology training. Our initial experiment data set includes bone radiographs, digital subtraction angiograms, and axial Computed Tomography (CT) slices. Preliminary results indicate that expert viewers (e.g., board-certified radiologists) were able to use EMT to successfully guide novice readers (e.g., software developers) with no medical training through search and gaze protocol patterns.

We anticipate using human performance data and lessons learned from our radiology training experiments with EMT to identify and investigate other potential training that can benefit from EMT. We will also identify EMT technology enhancements that can benefit the EMT/training experience, including active and passive software-driven queueing, metrics collection, and the use of AI/ML to replicate expert viewer behaviors.

Social Media Synthesis using AI for Decision Support

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22175

Social media is pervasive throughout today's society. Reports of, and reactions to, events can propagate locally, nationally, and internationally almost instantly, and can themselves trigger a cascade of reactions and events. Within this reality, we believe that it is important for any large-scale simulation of an engaged population using human behaviour modelling to incorporate social media. This paper reports on the design, implementation, and integration of the social media component within a broader simulation of Greater London with application to decision support systems, the training of decision makers, and course of action analysis. Within the social media component, live social media messages were combined with synthetically generated messages and presented in real-time, while analytics aggregating sentiment expressed in the messages were displayed to decision makers throughout the course of the simulation. The synthetic messages were generated by a trained AI model; each was related to the different emotions of happiness, sadness, fear, anger, joy, surprise and assigned to a member of the simulated population. The integration of an externally triggered event in the simulation, a power outage, resulted in a change in behaviour of the simulated population and consequently a change in the resulting tone and emotion reflected in the synthetic social media messages. Finally, initial user feedback is reported, and considerations for additional factors to influence the synthetically generated social media content based on cognitive state, demographic attributes, and extensions to the AI models are discussed.

Automation and Augmentation on Human Performance in eVTOL Flight

Samantha Emerson, Maria Chaparro Osman, Cait Rizzardo, Kent Halverson, Steve Ellis, Andrew Anderson, Don Haley

22232

Currently, over 600 electric vertical takeoff and landing (eVTOL) aircraft are in production (Vertical Flight Society, 2022). This new class of aircraft will require its own flight standards and curricula to train a new generation of pilots. However, to date, no data on eVTOL flight performance exists to build these standards or curricula. In this paper, we examine the influence of sets of eVTOL flight features that are human-controlled, automated, or augmented on human flight performance. In a quasi-experimental design, simulated flight performance was measured across two groups of participants (ab initio = 40, rated pilots=40) and two eVTOL aircraft. Both eVTOL aircraft are in the prototype phase and vary in the extent to which sets of flight controls are automated and augmented. A simulated flight profile was designed involving a series of waypoints in an urban environment that requires multiple takeoffs and landings. Participants repeated the same profile six times, demonstrating a variety of eVTOL flight competencies including hovering, takeoff, landing, and basic aircraft control. Each competency was broken down into different phases of flight determined by changes in the direction of momentum. Performance was measured using a multi-modal assessment approach including 1) system-based objective data from the simulator representing physics data and 2) an observer-based assessment tool that captures ratings from experts. Data collection is currently underway and will be completed in Summer 2022. We predict that, in general, flight performance will improve with greater levels of automation and augmentation; however, particular attention will be given to scenarios where this is not the case and to situations in which automation and augmentation lead to reduced flight knowledge (as assessed by pre-/post-test). Results of the experiment will be used to inform eVTOL flight standards, develop training programs, and influence design decisions in the aircraft.

Virtual Reality Testbed for Multi-Human Multi-Agent Adaptive Teamwork and Training

Joseph Salisbury, Ross Bobb, Virgil Barnard, William Casebeer, Ph.D., David Huberdeau

22240

Intelligent agents capable of learning and adapting to new data and changing contexts on the fly will require humans to fluidly adapt with their autonomous team members. Individualized, socio-emotionally intelligent technologies that continuously promote the emergence of team cohesion in novel groups of humans and intelligent agents are necessary to maximize collective adaption to rapidly evolving environmental demands. Here, we describe a virtual reality framework for the design and evaluation of operator-aware intelligent agents that can: prepare humans to work with autonomous technologies; train artificial intelligence to understand and evolve symbiotically with humans; and discover methods for enhancing performance of heterogenous multi-human multi-agent teams. Networked virtual reality clients allow human users to collaborate on tasks in an immersive, physics-based simulation environment. Integration of physiological monitoring devices enables biometrics to be collected and analyzed in real-time to provide individualized feedback and support. Combined with individual and group performance measures, objective metrics provide a basis for evaluating the impact and adaptability of artificial intelligence capabilities. To demonstrate this framework, we have developed a dismounted soldier squad combat scenario. Combat simulations are used to train algorithms to detect and track threats, predict outcomes, and provide feedback to coordinate squad tactics based on individual and group factors. Integration of these artificial intelligence capabilities into the virtual reality environment enable human-in-the-loop evaluation of their impact on multi-human multi-agent teamwork.

Mixed Reality and the Multi-Capable Aircraft Maintainer

Thomas O'Brien

22253

As the Air Force postures aircraft maintenance manning requirements in a time of low maintainer retention and in an ever growing contested environment, it is vital to find ways to yield a greater return from the human capital investments the Air Force has made. One such effort highlighted in Air Force Doctrine Note 1-21, Agile Combat Employment (ACE), is the employment of Multi-Capable Airmen (MCA) with a diverse foundational set of skills capable of performing tasks outside their core Air Force Specialty (AFS). The ability to field and sustain these diversely capable Airmen are the key to the success of the operational concept of ACE to support Joint All-Domain Operations. When applied to aircraft maintenance there is no doubt that the MCA is vital to the success of ACE, but it is clear that the value of an MCA maintainer exists operationally in both peacetime and wartime environments with the sole question residing in how to properly grow and sustain an MCA maintainer in order to overcome the inherent risks of trying to do more with less. The purpose of this paper is to detail the application and value of Mixed Reality (MR) immersive technology as applied to aircraft maintenance MCA in peace and wartime operations. Through cost analysis and research, this project evaluated the potential to use MR technology to supplement on-site engineering and 7-level technical proficiency worldwide through the force projection of out-of-theater human resources, as well as its use in a contested environment through force projection and protection. Results lead to potential risk avoidance in MCA proficiency gaps through projecting expertise in existing human capital, the reduction in MCA training requirements and costs, as well as the suitability and scalability of MR technology in peace and wartime environments to other Air Force and Department of Defense specialties.

Performance Considering Autonomy Level in Partially Autonomous Vehicles

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22269

To fully utilize the abilities of current autonomous vehicles, it is necessary to understand the interactions between the vehicles and their operators. Since the current state of the art of autonomous vehicles is partial autonomy that requires operators to perform parts of the driving task and to be alert and ready to take over full control of the vehicle, it is necessary to know how the operators' abilities are impacted by the amount of autonomy present in the system. Autonomous systems have known effects on performance, cognitive load, and situation awareness, but little is known about how these effects change in relation to distinct, increasing autonomy levels. It is also necessary to consider these abilities with the addition of secondary tasks due to the appeal of using autonomous systems for multitasking.

The goal of this research is to use a web-based virtual reality study to model operator situation awareness, cognitive load, driving performance, and secondary task performance as a function of five distinct, increasing levels of partial vehicle autonomy first with a constant, low rate of secondary tasks, and then with a steadily increasing rate of secondary tasks. The study had each participant operate a virtual military vehicle in one of five possible autonomy conditions while responding to questions on a communications terminal. After a practice phase for familiarization, each participant took part in two drives where they would have to intervene to prevent crashes regardless of autonomy level.

For both phases, the factors of scored driving performance, secondary task performance, subjective situation awareness, and cognitive load, were analyzed in terms of how they related to the autonomy level and to each other. Results are presented in the form of statistical analysis and modeled equations and show the potential for optimal multitasking within specific autonomy levels and task allocation requirements.

Tackling the Human Performance Data Problem: A Case for Standardization

Alexxa Bessey, Luke Waggenspack, Brian Schreiber, Wink Bennett, Ph.D.

22289

Over the past few decades, simulator use has increased greatly, due in part to its cost-efficiency and ability to provide training experiences that would be impractical or unsafe to conduct otherwise (e.g., emergency procedures). This increase in simulator use has coincided with an explosion in "big data," more specifically, human performance data that are collected from a large number of learners (n), measured variables (v), and measurements per unit time (t) (Adjerid & Kelley, 2018). However, as the resulting corpus of human performance data expands, it becomes increasingly more difficult to mine for trends. Resulting in a large pool of recorded data that is not immediately useable without extensive workarounds, manpower, or software algorithms. For example, consider the use case of simulated Air Force engagements. At any single Air Force training facility, there could be simulator records from hundreds of training scenarios per year with a variety of different characteristics (e.g., offensive counter-air maneuvers, defensive counter-air maneuvers, two-ships, four-ships, etc.). However, certain limitations of the data, such as unstandardized start and stop times of the engagements, hinder the ability to easily mine the data for historical norms, proficiency, or other human performance outcomes. As a result, the ability to interpret or draw conclusions from the data is much more limited, despite the robust pool of data. In this paper, we present the findings from a multi-year research and development effort that focuses on extracting meaningful human performance metrics from a "data lake" of roughly 3,500 data recordings that represent 10,000 training scenarios over the course of more than 15 years. We present best practices and lessons learned for parsing the data lake contents so that readers can better understand the implications of data limitations and how to address them in their own work.

Human-Autonomy Teaming in Immersive Environments

Haochen Wu, Bogdan Epureanu, Charne Folks, Jonathon Smereka, A. Emrah Bayrak

22323

Autonomous agents are increasingly thought of as team members alongside humans in large-scale operations. Both autonomous agents and humans have inherent advantages and limitations that might affect the outcome of an operation. The inclusion of autonomy within a team requires a significant effort to prepare autonomous agents to interact with human decision-makers. A fundamental challenge emerging is how to train humans and autonomous agents to achieve the operation goals with maximum performance. In this paper, we develop a game-based platform to train and quantitatively analyze the performance of human-autonomy teams in a disaster relief scenario. This framework consists of multiple interfaced components that allow a human decision-maker to collaborate with autonomous agents in an immersive virtual environment to accomplish a mission without cognitive overload. The disaster relief scenario is simulated in a high-fidelity environment using Unreal Engine where a human decision-maker interacts with the environment in real-time using a VIVE virtual reality headset and controllers. Autonomous agents possessing various capabilities are trained separately using a decentralized artificial intelligence algorithm to allocate tasks and collaborate with team members through reinforcement learning. Physiological data including pupil dilation, heart rate, and sweat gland activity are measured from the human during the time of the operation. This data is input to a trained machine learning architecture to monitor the cognitive task load and situation awareness of the human during the operation. To reduce the cognitive load of the human during operation, an adaptive user interface is constructed as a virtual tablet in the game engine to assist the human in decision-making depending on the cognitive load status. The developed game-based framework provides insights into the interactions of a human with multiple autonomous agents in time-critical operations. The immersive environment is a fundamental modeling and simulation tool for further developments and design of human-autonomy teams.

Multimodal, Adaptable, and Dynamic Human Autonomy Team Relationships

Daniel Barber, Lauren Reinerman-Jones, Ryan Wohleber, Jeremiah Folsom-Kovarik

22328

The military operates in dynamic and complex task environments with inherent uncertainty that can make it difficult for human operators to form appropriate strategies when using autonomy. Uncertainty about system capability often results in disuse or misuse of autonomy, and as a result, performance and situation awareness are compromised. A key component in successful teaming is trust. Methods of transparency are emerging to support human-autonomy teams (HATs) by communicating information about autonomy's actions, decisions, behaviors, and intentions to develop shared awareness and shared intent. Most efforts investigate transparency during task execution, but there are limits to how efficiently transparency content is communicated in these settings. DARPA recently conducted exercises with swarms of drones demonstrating the inability of an operator to respond appropriately despite system transparency. Given that and the ability to process at high speed, HAT operation might prohibit information delivery and operator perception and comprehension of the information about system behaviors, states, plans, and rationales before action must be taken. Consideration of transparency information during task performance can siphon valuable mental resources during high task load, and lack of spare mental capacity during these periods limits the ability of operators to learn and retain insights about how the autonomy functions. Addressing operator limits, implementation of transparency beyond mission execution must be sought. This paper presents research integrating multiple methods of transparency and applying them to different phases of a HAT lifecycle (e.g., pre, during, and post task) within the domain of counter small, unmanned air systems. Two important questions are explored: 1) What is the impact of this method across the HAT lifecycle to common ground, trust, communication, and reliance (e.g., pre, during, and post task), and 2) How do HAT interactions over time shape and change transparency communication needs?

EEG Features for Assessing Skill Levels During Laparoscopic Surgical Training

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22338

Objective: In this study, we evaluated differences in the brain activity between expert surgeons and novice medical residents based on electroencephalography (EEG). We used the EEGlab toolbox for data analysis and classification using Common spatial pattern (CSP) analysis.

Methods: 10 expert surgeons and 10 novice medical residents were recruited at the University at Buffalo after IRB approval. After informed consent, the subjects performed three trials of laparoscopic suturing and knot tying with rest periods in-between the task trials. 32-channel EEG was performed during the task performance that was used to analyze spatial patterns of brain activity. CSP analysis was used to distinguish the brain activity of expert surgeons from novice medical residents.

Results: CSP analysis identified the significant channels based on the maximum of the spatial pattern vectors at the scalp. While novices had primarily frontal cortex involved for a maximum of the spatial pattern vectors at the scalp, the experts had the hotspot of the spatial pattern vectors over frontal and parietal cortices. Simple linear discriminant analysis with 10-fold cross-validation achieved more than 90% classification accuracy using the spatial pattern vectors at the scalp.

Conclusion: CSP analysis can identify an optimal set of channels for evaluating the differences in brain activity between expert surgeons and novice medical residents. CSP analysis also provided the features for a simple linear discriminant analysis to classify expert surgeons versus novice medical residents using an optimal set of channels overlying frontal and parietal cortices.

A Smart Approach for After Action Review Visualization and Analysis

Christopher Young, Richard Schaffer, Jennifer Phillips, Ph.D., Allison Hancock, Ph.D., Marc Pfahler, Marcus Mainz, Luke Cardelli, Breck Perry, Gwen Campbell, Ph.D., Audrey Zlatkin, Costas Koufogazos

22371

Live field training is essential to the preparation of Marines and Marine units. No other training environment can approximate real-world combat conditions including time pressure, the fog and friction of war, and in the case of force-on-force training, a dynamic adversary. The subsequent after-action review (AAR) is where most learning takes place. An effective AAR facilitates reflection by providing feedback on individual and unit performance so that strengths can be sustained and deficiencies, corrected. The purpose of the Office of Naval Research's Streamlined Marine After-Action Review (AAR) Tool for Visualization (SMART-Viz) research and development effort is to optimize learning and the development of expertise with data-driven feedback on unit performance.

The SMART-Viz research program uses high-fidelity, integrated, intelligent AAR tools to capture objective data about what occurred rather than subjective perceptions, and visually reproduce the events of the battle across the warfighting functions. The SMART-Viz tools rapidly synchronize data from instrumented sources and observers to provide information about tactical events paired with cognitive and behavioral performance assessments of decision making. Individual and unit performance measures are displayed in an analysis dashboard combining a visual representation of ground truth on the battlespace, battle outcomes, and performance measure graphics. Expected results include increases in the volume and objectivity of data available to AAR facilitators and utility of the data for pinpointing performance deficiencies and delivering visual battle replay feedback that promotes comprehension and learning. This paper describes the measures forming the foundation of the AAR analysis and early results drawn from Marine Corps exercises including battle outcomes and measures of decision making. Specifically, outcome measures of survivability, lethality, and mission accomplishment were collected via data logs and sensors. In addition, quality measures of commander and staff decision making from observer ratings were collected and tested.

The Effect of Environment Immersivity on Perspective-Taking Task Performance

Michael Kozhevnikov, Maria Kozhevnikov

22376

The main goal of this study was to examine the effect of different viewing environments on the performance of a spatial perspective-taking task. The spatial perspective-taking task is an egocentric task in which viewers are asked to change their perspective mentally and point to a target from an imagined perspective. The task requires egocentric encoding (the stimuli are encoded in relation to the viewer's body) and transformation (the viewer imagines own body changing its orientation to face a new perspective). Twenty-four participants were administered a computerized perspective-taking task presented in three different viewing environments of increased immersivity: traditional computer desktop (2D), three-dimensional large projector screen (3DPS), and fully immersive virtual environment (3DVE) offered through the use of the head-mounted display.

Participants exhibited a similar linear dependence of accuracy and response time on the magnitude of imagined heading in all three conditions. Furthermore, all three conditions were not significantly different in their response time or accuracy. However, as immersivity of an environment increased, the number of egocentric errors, related to the confusion between left and right, front and back, also increased. In contrast, the number of adjacent errors, representing allocentric strategies and related to under-rotating or over-rotating the objects, decreased. The results suggest that although large projector screens provide a higher degree of immersivity than conventional 2D displays, in contrast to fully immersive 3DVEs, they are insufficient to ensure the dominant use of an egocentric, viewer-centered frame of reference.

Accessing the States of Enhanced Cognition: Implications for Military Mission Preparation

Maria Kozhevnikov

22398

Enhanced Cognitive States (ECSs) have been operationalized as dramatic transient enhancements in temporal and visual-spatial aspects of attention, accompanied by the state of parasympathetic nervous system (PNS) withdrawal-associated arousal. Previous research has shown that ECSs can be elicited during “adrenaline-rush” FPS (first-person shooter) games involving highly adventurous features (e.g., shooters, survival, horror, fantasy). In Experiment 1, we examined the role of a player's perspective in reaching the ECSs, by comparing the changes in the performance on the focused attention task and electrocardiographic (EKG) data of expert video gamers who played, on two different days, first-person and third-person adventurous video games (Unreal Tournament and Metal Slug, respectively). In Experiment 2, a group of expert video gamers who played an FPS game for 30 minutes and exhibited significant increases in the temporal aspects of attention, reflecting the ECSs, was examined on the tasks, measuring conflict resolution and verbal working memory. The results suggest that the first-person perspective is critical for accessing the ECSs, as the players experienced the ECSs only during the Unreal Tournament but not Metal Slug. Furthermore, participants in ECSs improved significantly on conflict resolution but not verbal working memory, suggesting significant enhancements of executive attention during the ECSs, but not necessarily domain-specific capacities. The project results suggest possibilities for consciously accessing latent resources of our brain to temporarily boost our cognitive capacities on demand (e.g., providing military personnel with video-game training before short-burst missions).

Exploring the Ability to Employ Virtual Entities Outdoors at Ranges Beyond 20 Meters

John Morris, Perry McDowell, Quinn Kennedy, Clay Greunke, Kevin Hernandez, Michael Maulbeck

22407

The Army is procuring the Integrated Visual Augmentation System (IVAS) system to enable enhanced night vision, planning, and training capability and is researching the functionality of the IVAS system to maximize its effective implementation. One known limitation of the IVAS system is the limited ability to portray virtual entities at far ranges in outdoor environments due to light

wash out, accurate positioning, and dynamic occlusion. This significantly limits the ability of IVAS to support training outside of outdoor close combat environments.

The primary goal of this research was to evaluate fixed three-dimensional visualizations to support outdoor training for fire teams through squads (9-12 personnel). Doing so required enabling target visualizations for 3D non-player characters or vehicles at ranges up to 300 meters. We evaluated these visualizations by conducting a study to determine the realism of virtual objects displayed as part of the real world.

Preliminary efforts included working with Virtual Reality Rehab to develop software which tied GPS locational data with virtual entity placement, and employment of sensors to adjust device light levels to produce more realistic rendering of virtual objects.

This study will be conducted from March through April and will include 10-20 active-duty military test subjects visualizing virtual personnel, buildings, and vehicles in three scenarios located on the NPS (Naval Postgraduate School) campus using a HoloLens II. Outdoor location considerations included shadows, background clutter, cars blocking the field of view, and the sun's positioning. Users will provide feedback on identifying the type of object, and the difficulty in finding the object.

We predict increased effectiveness out to 200 meters, but limited to no improvement of virtual visualizations beyond 200 meters due to background clutter and multiple light wash-out layers. Results will inform ongoing and future research related to the IVAS Squad immersive Virtual Trainer and live/virtual training.

Inferring Player and Team Models in a Minecraft Search-and-Rescue Task

David Pynadath, Volkan Ustun, Nikolos Gurney, Stacy Marsella, Hala Mostafa, Pedro Sequeira, Peggy Wu

22410

While autonomous agents offer the promise of automated assistance for human teamwork, the usefulness of such assistance is limited by an agent's ability to understand the people it wants to help. No matter how well defined and tightly scoped a task is, people will always bring their diverse preferences, experiences, biases, etc. to bear even when acting as a team. An agent that can neither represent the heterogeneity across the team it will have to help, nor infer the subjective frame of reference of the individual team members, is doomed to apply a one-size-fits-all policy of assistance that is unlikely to maximize task performance. In this work, we present a methodology for first capturing the diversity across different people within an agent's initial hypothesis space and then using observations of a specific person's behavior to update posterior beliefs within that hypothesis space. For the former, we apply inverse reinforcement learning (IRL) to analyze a sample of human behavior at a task and then extract reward functions that best explain that behavior. For the latter, the agent uses a Bayesian Theory of Mind, by applying Partially Observable Markov Decision Processes, filled in by the IRL output, in a recursive manner to form beliefs about the type of people it is currently observing. We evaluate the effectiveness of this methodology using a search-and-rescue task in Minecraft and show the impact of different levels of granularity in the hypothesis space on the accuracy of the agent's inference about the human players and teams.

Adaptability for Human Performance Excellence: Updating the Conceptual Model of Expertise for the Modern Work Environment

Coreen Harada, Ashley Inbody

22431

Three industrial revolutions shaped the modern world: the steam engine, assembly line, and digital technology. We are now in the midst of the fourth – the convergence of physical and technological worlds. Up to now, individuals have fulfilled roles based on a prescribed, relatively narrow level of expertise; successful adaptation to modern workplace systems and bridging the gap between existing and future needs requires a shift from rigid, defined roles to flexible, adaptive skillsets (World Economic Forum, 2018).

Traditional, pre-convergence models of expertise conceptualize development from novice to expert as a function of learning over time, where high level expertise may be obtained with sustained effort and performance feedback (Chi, 2006; Dreyfus & Dreyfus, 1980; Ericsson & Lehmann, 1996; Hoffman, 1998). Much attention is given to observable performance, with far less concern about the thought processes underlying the behavioral outcome. For example, performers may be seen as improving when they incur fewer errors, increase accuracy, and decrease response time (Chi, 2006; Dreyfus & Dreyfus, 1980; Hoffman, 1998). Not accounted for are discrete improvements that may be applicable beyond the task at hand, such as increased knowledge, emotional regulation, and use of metacognitive skills, and decreased cognitive load (Eccles & Feltovich, 2008).

The modern workplace system has evolved beyond predictable task-based proficiency; to thrive in today's world, individuals must be able to adapt to novel challenges and demands. This requires adaptive expertise, which involves the successful application of acquired skills to new arenas and represents an extension beyond most existing proficiency measures.

This paper presents a conceptual model for metacognitive skill development that supports adaptive expertise, which was developed and tested with U.S. Army Soldiers. This paper also describes prospective approaches to leverage our empirical understanding of metacognitive skills to augment Service Member development and effective performance in real-world, novel settings.

POLICY, STANDARDS, MANAGEMENT, AND ACQUISITION

BEST PAPER

Enhancing the Total Leaning Architecture for Experiential Learning

Mike Hernandez, Robby Robson, Ph.D., Timothy Welch, Fritz Ray, Benjamin Goldberg, Ph.D., Kevin Owens, Shelly Blake-Plock

22461

Defense-wide efforts are underway to modernize learning technologies and increase capabilities related to warfighter performance. Many investments focus on discrete training experiences, which does not provide a platform for longitudinally assessing the competencies and progression of learners or the efficacy of training systems. Longitudinal assessments are needed both for training purposes and to support the transfer of training systems into the acquisition process.

The STE (Synthetic Training Environment) Experiential Learning for Readiness (STEEL-R) project addresses the challenge of gathering and analyzing longitudinal training and performance data by establishing a common data interoperability layer that collects evidence through a competency-based experiential learning model. The STEEL-R architecture is based on and extends the US Advanced Distributed Learning (ADL) initiative's Total Learning Architecture (TLA) to function across an ecosystem of synthetic and live training environments. This approach provides data traceability, supports evidence-based training decisions, and results in datasets that can inform acquisition teams and reduce the need to manually collect data when transitioning from research to acquisition.

This paper starts by presenting the STEEL-R architecture, in which xAPI, the Generalized Intelligent Framework for Tutoring (GIFT), Learning Record Stores (LRSs), and the Competency and Skills System (CaSS) - all open source and developed for the DoD - play central roles. GIFT is used to orchestrate data from training exercises ranging from game-like VBS exercises to live field exercises in which soldiers are equipped with wearable sensors. The paper then discusses the data models used and data is collected over time and transformed into standardized patterns that can be used to produce fully traceable evidence-based decisions concerning trainees. The last section of the paper discusses the implications of this approach for evaluating system performance and how this work will aid DoD acquisition teams.

Step One: Install Plumbing – Criticality of Data Management for AI/ML

Anastacia MacAllister, Ph.D., Daniel Javorsek, Ph.D., Louis Dube, Patrick Rupp

22114

Artificial Intelligence (AI) and Machine Learning (ML) are the new must have technologies for both commercial industry and the Department of Defense (DoD). The budget and number of projects related to AI/ML in the DoD is continually increasing, with a 50% jump anticipated in 2022 alone. In addition, the National Security Commission on AI recommends doubling research funding for AI/ML until it reaches $32 billion in 2026 which still pales in comparison with the $209 billion spent by China in 2021. With this funding drive, the stakes for this emerging disruptive technology development are high. Failing to properly develop and employ AI/ML can hamper readiness for decades and creates the risk of falling even further behind peer competitors.

To ensure the technology delivers, government and industry need to learn from previous projects in this fast-paced arena to develop sound AI/ML implementation strategies. Unfortunately, more attention is paid to flashy new AI/ML algorithms or computing enhancements rather than sound deployment fundamentals. Ultimately, algorithms and hardware are only tools and are a small part of the whole process. Less glamorous topics like data and process management are arguably more important to ensuring success. Data infrastructure and process management encompasses topics like data collection, data cleaning, data formatting, data storage, feature extraction, and configuration management. These pieces create the underlying infrastructure, or plumbing, required to build robust and tactically relevant AI/ML in the real world rather than the lab. This paper describes best practices learned from several DoD AI/ML projects. Specifically, this paper outlines policies, standards, and management practices required for establishing the pluming required to ensure successful AI/ML project execution culminating with an F-35 enterprise case study on Knowledge Management (KM). Ultimately, our goal is to help kickstart the discussion in the community about best practices associated with this disruptive emerging technology.

Effectively Integrating Technology into Wargames

Jennifer McArdle, CMSP, Eric Hilmer

22123

Wargames have long been touted as a key avenue to imagine and prepare for the contours of future competition and conflict,but there is general agreement among professional wargaming stakeholders that aspects of game design, execution, and analysis are ripe for technological disruption. The professional wargame construction process has not maintained pace with technological advancements in the commercial gaming world. The disparity between professional wargames and the commercial games market, however, is understandable. Wargames serve different purposes to commercial games. Professional wargames support analytic and experiential military goals– they help the military develop new insights or educate and train its critical workforce. As a result of these differences, elements of the professional wargame construction process may not lend themselves to technological solutions, or when they do, those solutions may be fundamentally different than those in the commercial marketplace. Additionally,due to the nature and goals of some wargames,questions remain on how feasible technology disruption is within wargaming writ large.

Drawing on more than three dozen interviews and conversations with members of the professional wargaming community on the strengths and weaknesses associated with current technology-based wargame offerings, a technology survey with War on the Rocks that elicited over 700 respondents of self-identified wargaming professionals,and a detailed assessment of the wargame construction process,this article outlines the areas where technology is best suited to enhance wargame design, construction, and analysis. Perhaps more importantly, and somewhat counterintuitively for two authors working in industry at a technology company, this article also identifies areas where technological skepticism among some wargame designers is warranted.

State Antifragility: An Agent-Based Modeling Approach to Understanding State Behavior

Rebecca Law, Ph.D.

22124

This paper takes an interdisciplinary approach to understanding what makes states antifragile and why this matters by constructing a parsimonious, first of its kind agent-based model. The model focuses on the key elements of state antifragility that reside along a spectrum of fragility and transverse bidirectionally from fragile to resilient to antifragile given a certain set of environmental conditions.

First coined by Nicholas Nassim Taleb and applied to economics, antifragility is a nascent concept. In 2015, Nassim Taleb and Gregory Treverton's article in Foreign Affairs outlined five characteristics of state antifragility. This project aims to advance the study of antifragility in the context of the nation-state beyond these initial contributions by (1) development of three propensity variables associated with antifragility, (2) a new agent-based model to investigate antifragility, and (3) applying the findings of the model and the propensity score theorizing to two case studies.

This research posits three propensity variables for a state to become fragile, resilient or antifragile. These variables include learning, power conversion, and agility. Cumulatively, these variables comprise a state's capacity for dealing with various stressors in the international environment. The agent-based model captures the behavior of a single state when confronted with a stress in a variety of scenarios, forming an essential building block for future work (hinted at in the case studies) involving the interaction between states. The case studies show how the propensity variables, and the model results provide the basis for a distinctive and relatively novel evaluation of the historical record involving the history of the United States in and with Iraq, and the evolving great power rivalry between the United States and China, emphasizing the value of taking antifragility seriously in the context of International Studies.

Exploiting Competence Data to Support Military HR System Management

Commander Robert Floyd

22130

Military human resources (HR) systems must generate and sustain the human capability that underpins fighting power. Literature has documented significant challenges that modern military HR systems must overcome, including both skills shortages and also surpluses in some military trades and ranks. The literature has also emphasised the central role for data (notably 'Big Data') and exploitation of that data (notably via Artificial Intelligence (AI)) in developing solutions to these challenges. The Royal Navy (RN) has recently amalgamated previously separate Personnel and Training functions into an integrated Directorate of People and Training covering the breadth of HR areas: appropriate use of data is essential to enable shared understanding of what is happening within the RN HR system, to assess whether progress is being made towards desirable outcomes and to aid management decision making. However, UK defence training and personnel policy has provided very little detailed guidance on how competence data can or should be used to meet current human capability challenges.

This paper sets out a methodology for using existing HR data, including competence requirements of job roles and competence qualifications held by service personnel, to enable better understanding and ongoing measurement of human capability within seagoing Royal Navy (RN) units. Findings are based on the author's analysis of real HR data held within the UK Ministry of Defence's HR Management Information System (MIS) using analytics tools within the MIS. However, illustrative synthetic data is used to present findings while avoiding publication of potentially sensitive details. From this, the paper develops principles and recommendations to inform and guide management practices for training management and personnel management to improve the provision of human capability.

Analyzing the Motivation for Adaptive Instructional System (AIS) Standards

Robert Sottilare, Ph.D.

22141

This paper will analyze the requirements, costs, and benefits of establishing standards and recommended practices for a class of education technology categorized as an adaptive instructional system (AIS). AISs accommodate individual differences by tailoring instruction to facilitate learner knowledge acquisition (Wang & Walberg, 1983; Tsai & Hsu, 2012). They guide one-to-one learning activities that exercise skills defined by learning objectives (Sottilare & Brawner, 2018), and they use artificial intelligence (AI) and other advanced technologies to help people learn more effectively and efficiently (AIS Consortium, 2021).

The growing use of AISs in military training, pre-K, K-12, higher education, and adult learning contexts has prompted the AIS community (learners, instructors, instructional designers, system developers, testers and evaluators, and system providers) to initiate IEEE standards. An IEEE working group is managing the development of AIS standards and recommended practices under Project 2247. The initial focus of the Project 2247 working group was to develop a conceptual model of an AIS, its primary components and features. Other efforts have begun to focus on AIS interoperability standards to promote reuse and recommended practices for the fair evaluation of AIS performance capabilities.

While the motivation for AIS standards requirements may be evident, the contributing factors to standards costs and benefits has yet to be fully explored. Although infrequently considered by learning science researchers, cost factors can be as critical as effectiveness in improving the state-of-art and state-of-practice in both training and education. This paper will discuss recommendations for various standards and practices arising from the AIS community and analyze the business case for advancements and opportunities provided by each recommendation in a training and education context. Standards recommendations are grouped by the following categories: policy, authoring and curation tools, learner modeling, domain modeling, instructional strategies and assessments, and interface design standards.

Enabling a Sharing Economy to Accelerate Change in Immersive Training

Krissa Watry, Christina Padron, Victoria Claypoole, Ph.D., Stephen Hopp, Margaret Merkle

22188

Training and simulation products developed and deployed for the government should target a common operating environment that expects compatibility, interactivity, and security. Diverse, training application and content developers generally do not create standardized or interoperable software environments, leaving large organizations with stovepipes of content that is challenging to integrate and manage. New models of continuous integration/continuous deployment environments, such as the USAF Platform One, establish unified delivery spaces for software development, but do not yet support a unified training system for specialized content development. Building virtual, augmented, and mixed reality (extended reality, or XR, collectively) training systems, training content, and enabling technologies using a modular open systems approach (MOSA), provides the opportunity for a central hub which allows discovery, distribution, and reuse of different types of digital assets (e.g., XR applications, XR lessons, 3D models, AI/ML models, assessment tools, visualization tools). Enabling the hub to support a sharing economy that features the authors of the digital assets demonstrates the conceptual advantages of open-source development to the training systems and training content marketplace. There are still process, programmatic, and contractual challenges, and considerations, including how to define who can access, share, re-use, and modify assets, and how author credit designation and/or license fees might be handled. Ensuring that a central hub respect data rights, incentivize contributors and fuels a collaborative ecosystem is imperative to the success of a centralized hub. This paper describes the design, development, and instantiation of a centralized hub for the discovery and distribution of immersive, XR training technologies. The methodology for overcoming some of the challenges is discussed, with preliminary results from several pilot programs with over 30 individual third-party training application vendors. Finally, the paper concludes with a discussion of lessons learned and future considerations for leveraging a centralized hub to accelerate change in immersive learning.

Technology is the Easy Part: Transforming Business Processes for Interoperability

Ashley Howell, Andy Johnson, Anne Marie Dinardo, Sae Schatz, Ph.D., Lora Muchmore

22202

DoD seeks to implement a learning ecosystem to radically change education and training enterprise-wide by leveraging data-centric advanced technologies at scale. However, despite the technological feasibility of this vision, organizational and cultural barriers limit its achievement unless the Department's business processes are readdressed.

As such, a business process reengineering effort led by the Chief Innovation Officer for the Information Enterprise in the DoD Chief Information Office and the Advanced Distributed Learning Initiative within the Defense Support Services Center, kicked off in January 2022. This process reengineering effort supports Enterprise Digital Learning Modernization (EDLM), a reform that shifts DoD away from legacy learning technologies to interoperable systems of systems.

This process reengineering effort started with a workshop with over 135 military and civilian contributors, representing all Services and major Components. They identified barriers to implementing EDLM including lack of DoD-wide shared services, perceived issues with secondary policy blockers, lack of necessary workforce skills, challenges navigating data governance, a perceived lack of program-level leadership support, lack of transparency and communication across domains, learning technology acquisition challenges, and lack of return-on-investment data for implementing change.

Additionally, the DoD Chief Data Office unveiled its VAULTIS data interoperability maturity model—designed to serve as a fast, uniform way to assess organizations' data postures for interoperability. Specifically, the model lays out seven goals to make data visible, accessible, understandable, linked, trustworthy, interoperable, and secure. This model creates benchmarks for data maturity, which will help mark EDLM's transformation progress.

In this paper, we use EDLM as a case study, highlighting real-world barriers to technology modernization—in particular to interoperability—and detailing the business process improvement approaches used to overcome them. This is an empirical paper with generalizable principles and recommendations grounded in the field of Business Process Reengineering.

Optimizing Simulators Logistics & Product Support

Richard Swain, Joseph Gerling, Christal Green, Christopher Covert, Michael Baldwin, Tonita Davis

22213

Planning and executing the movement and support of training and simulation products at the speed of operator relevance remains a critical enabler to affordable readiness. Continuous improvement is required within each training and simulation program and through measuring integrated support strategies with platforms. How these functions are packaged to field and maintain readiness and the operational capability of training and simulation products, subsystems, and components, and then doing so within standardized and interoperable environments, is the near-term focus.

Simulators Logistics & Product Support optimization is focused on tools to enable a cross-domain training architecture, on facilitating a synthetic-to-live/live-to-synthetic capability, and on actions supporting aggressive movement toward the digital Air Force. What will be the new sustainment strategy given each program decision? Optimization efforts will include results from gaming research integration for learning, development of a Learning Management System, and Model-Based Engineering (MBE) applications for product support. Joint discussions are expected to increase knowledge sharing.

Numerous challenges exist across multiple product domain applications, multiple Services with diverse internal Commands, industrial base intellectual property and market share, and program affordability. All stakeholders want a positive impact to strategy and with sustained operational effectiveness. This paper will examine logistics and product support pathways for program

delivery that will include driving common architecture and support tool cost avoidance; standardizing measurement of existing readiness baselines; enhancing platform-to-training system organizational relationships by Command then Service; leveraging industry and government strengths and best practices; and will initiate a Cost Per Simulation Hour planning/measurement capability. This paper will culminate with new methodologies for logistics and product support in a digital environment, a roadmap of lessons learned with targeted opportunities for future examination and knowledge sharing, guidance for workforce development, and will demonstrate how AF Simulator programs remain a trusted agile provider of innovative, timely, and cost-effective capabilities.

Strategic Planning for Aircrew Readiness: How MS&T Must be Balanced with Live-fly Experiences to Support Future Mission Goals

JJ Walcutt, Ph.D., Clay Percle, William Mott, Merrick Green, CMSP, Thomas Harley, Jay Spohn

22283

Aircrew readiness needs are changing rapidly yet historical technology and training practices cannot support these requirements. Specifically, the USAF's family of simulators have not kept pace with the necessity to integrate platforms for training resulting in stove-piped, limited training experiences and reduced readiness. Specific issues include a lack of congruence with current platform capabilities, inaccurate simulated threats and experiences, and a lack of access to high-end integrated simulation environments. Accordingly, the USAF conducted a study of graduate level pilots across 12 airframes to inform resourcing and advanced training gaps with a focus on "Night One" readiness.

Specifically, objective and subjective training and readiness data were collected to determine if current training and technology adequately support readiness across airmen in high-end platforms. Findings suggest there are several existing gaps that warrant immediate attention including: a) live-fly ranges do not meet 5th Generation, Electronic Warfare (EW), or integrated and contested training requirements, b) synthetic training venues lack sufficient fidelity, are overly scripted, and lack integration with multiple platforms resulting in negative training, c) high-fidelity synthetic training venues do not have the capacity to meet requirements and are cost prohibitive, d) distributed training networks do not support 5th Generation or EW training due to latency, and e) a multi-platform simulated environment that supports training for the contested high-end fight has not been developed. More plainly stated, "the Air Force's projected force structure in 2030 is not capable of fighting and winning against this array of potential adversary capabilities (USAF Air Superiority 2030)." Based on these data and the demand signal to modernize, key recommendations from the Strategic Aircrew Training Investment Strategy study regarding how to balance the need for live-fly experiences with the requirement to conduct high-end training and test in simulators will be provided.

Realizing Training Transformation through Feature Based Product Line Engineering

Brett Tainter, Randy Pitz

22340

Systems and Software Product Line Engineering (PLE) has gone mainstream in complex engineering environments and is being increasingly adopted by many businesses. We will provide an overview of the recently released ISO 26508: "Methods and Tools for the Feature-based Approach to Systems and Software Product Line Engineering" which is an automated approach for managing a product portfolio as a single entity with variation as opposed to products developed in isolation. There are numerous references that ascribe cost and efficiency benefits to organizations adopting a PLE approach, especially in the Aerospace and Defense sector.

However, realizing PLE adoption within simulation-based training systems has lagged other defense systems despite similar system complexity and reduced regulatory oversight.

The advantages of the PLE methodology includes documented benefits ranging from acquisition through development and sustainment. These benefits are no less relevant to the modeling, simulation and training community than the systems they are modeled after. The results achieved through this methodology can transform training by enabling more innovation throughout the development life-cycle.

The P-8 Mission Trainer architecture team is modernizing their development approach through use of PLE and Digital Engineering techniques to establish a single source of truth in a product line context. This approach is key to enabling the scalability of the product line as additional programs are added to the portfolio. The benefits are seen throughout the development life-cycle, across the concurrent baselines and is driving a culture focused on innovation. In this paper, we explore the benefits of PLE to large-scale training systems by primarily examining lessons learned from the Boeing P-8 training system architecture team along with supporting lessons found in other similar scale training system product lines.

SIMULATION

BEST PAPER

Semantic Fidelity Reckoning: Toward Normalized Simulation Interoperability in Digital Engineering

Ric Roca, Daniel Winton

22157

Semantic Fidelity Reckoning (SFR) extends and generalizes Dead Reckoning from Distributed Interactive Simulation (DIS) to convey, detect, and reconcile fidelity specification disparities among distributed analytic simulators. SFR is based on an emergent Semantic Fidelity (SF) paradigm originally aimed at normalizing fidelity specifications for computable models within analytic simulation systems. SF and SFR were examined in this study toward semantic interoperability and semantic validation & verification in distributed simulation ?not only among analytic simulators but also to enable the handshake across digital engineering (DE) domains such as between phenomena models of orbital mechanics and Model-Based Systems Engineering (MBSE) system architecture descriptive models of satellites and missiles. DE implies a dependency on semantic interoperability (i.e., information transmission; unambiguous contextual meaning in data exchange) which remains elusive among modeling & simulation communities-of-interest and DE enterprise efforts. Semantic interoperability has been riddled by arbitrary and subjective generic taxonomies, so-called domain ontologies, and parochial data models that focus on local needs ?all of which leads to information silos which require complex, costly, and often untenable cross-domain ontology/model matching algorithms to reconcile semantic gaps, conflicts, and contradictions. SF is grounded on a novel taxonomy that borrows from phylogenic systematics and other formal methods to promote a consistent and repeatable ontological approach within and across domains toward mitigating ambiguity and the need for costly ontology matching. The study involved a rudimentary distributed-simulator experiment of an anti-satellite missile intercepting a low Earth orbit satellite to demonstrate and provide results of error propagation of missile trajectory and satellite orbit due to disparate model fidelities as well as error mitigation with SF/SFR. Results also show how SF specifications enable the handshake between the analytic simulators and the Constraint Blocks of GENESYS/MBSE descriptive models which are traced to the MBSE operational environment system requirements, design, and risk among other element types.

A Cyber Attack Forecasting System

C Savell, Ambrose Kam, Brett Tucker, Nataliya Shevchenko

22117

GCAS, Inc., Carnegie Mellon University, and Lockheed Martin Corporation have partnered to research how to model and forecast a cyberthreat's future maneuvers in a compromised IT or OT network. Our approach is to use methods and models studied and developed for attack warning and attack assessment of ballistic missile defense, such as probabilistic multi-model filters and multi-hypotheses tracking, Specifically, a Multi Hypothesis Method (MHM) within a Bayesian framework is presented, including Utility and Game Theory

for decision making. The result is an approach for determining the most likely past threat vector and providing a prioritized list of most likely future maneuvers by the threat agent.

This proven technology is being leveraged to track and forecast cyberthreat attack vectors to effectively defend organizational high value assets and neutralize those threats. The approach has the advantage over current state of the art techniques (e.g., rule-based systems and neural networks) in that it adds the ability to predict the potential future next move in the attack vector.

A simple proof-of-concept study was performed, simulating a cyberattack by a single intruder with a limited number of maneuver tactics , which validated the feasibility of the approach.

Three planned outcomes of our research are:

Efficient algorithms and methods for predicting future movement of a cyberthreat, Cyber Simulation & Modeling (S&M) tool for digital twin, cyber wargaming, training and validating CMMC compliance, and An advanced probabilistic S&M system for modeling complex non-deterministic problems across a wide domain of applications.

Estimating Relative Combat Effectiveness Using Simulations

Per-Idar Evensen, Marius Halsør, Dan Helge Bentsen

22137

At the Norwegian Defence Research Establishment (FFI) we are often interested in assessing and comparing the relative combat effectiveness of different combat systems, for example to investigate which one of two, or more, alternative combat systems that solves a selection of tasks or missions best. In this context, a combat system can for example be a weapon system, a group of fighting entities, a force structure element, or a force structure.

There is no precise and unambiguous definition of combat effectiveness. However, combat effectiveness can in general be said to be a measure of a combat system's ability to solve a given task or mission, or a measure of how well a combat system solves a given task or mission. Combat effectiveness is affected by many different factors, and measuring and analyzing combat effectiveness is a complex and challenging task. Data from real-world warfare are often scarce, and for obvious reasons it is of course not possible to experiment with warfare in the real world. Modeling and simulation (M&S) is therefore essential for experimenting with, and assessing and comparing the performance and combat effectiveness of, different weapon systems and force structure elements. Combat models, however, are simplifications and will never represent all aspects of reality. Simulation of modern combat with sufficient realism is very challenging, especially when it comes to human factors.

In this paper, we discuss what combat effectiveness means from a conceptual, system-theoretic perspective, look at some definitions of combat effectiveness, and discuss the factors that can affect combat effectiveness. Moreover, we briefly describe and discuss some of the approaches for quantifying and measuring combat effectiveness that have been suggested in the literature. Finally, we present our general approach for using simulations and simulation-supported wargames to assess and compare the relative combat effectiveness of different combat systems.

Simulation-based Approach to Synthesizing Maritime Interaction Scenarios for Testing Autonomy

Benjamin Hargis, Yiannis Papelis

22147

As the desire to equip Autonomous Surface Vessels with increasingly complex autonomy grows, development of effective testing methodologies for autonomy-based behaviors is of importance. Traditional simulation-based single event testing, however, lacks the ability to evaluate the performance of autonomy algorithms before in-situ testing takes place. One issue with designing events in long-run simulations with multiple consecutive events is that the state of the system under test is not known before runtime. Therefore, methods for designing interactions that are specific, yet versatile and flexible are required. This paper presents a method to deterministically synthesize maritime traffic interactions that can be presented to a system under test regardless of the state of the SUT. The development was motivated by three factors. First, the developed method needs to allow a targeted interaction design. Second, the method should accommodate closed-feedback testing approaches that can select testing situations based on prior performance of the SUT. Finally, the method must facilitate testing time compression by reducing and/or eliminating time during the simulation when the SUT is not being stressed by external factors. The method was validated via a simulation. Various scenarios were designed, both trivial and non-trivial and the resulting interaction data was recorded. The overall approach and results presented here validate the use of this method to synthesize varying intensity maritime traffic interactions. Results indicate that the approach can enable more robust evaluation of maritime autonomous algorithms.

Integration of Live and Synthetic Environments for Improved Cyberspace Training

James Geddes, Michael Boyce, Ph.D., Omar Hasan, Jeffrey Welch

22161

In the modern battlespace, Army forces must be Multi-Domain Operations (MDO)-capable, and as part of the Joint Force, must be prepared to fight across all domains (Land, Sea, Air, Space, and Cyberspace), the Electromagnetic Spectrum (EMS), and the Information Environment (IE). Increasingly, in conjunction with traditional kinetic operations, threats target the Army's Radio Frequency (RF) connected elements to gain an advantage in contested environments, such as the disruption of Global Positioning System (GPS) and other Position, Navigation, and Timing (PNT) systems, and jamming of radio communications. To support MDO training in this complex operational environment, the Army's Live, Virtual, Constructive, and Gaming (LVC&G) training systems need to incorporate these Cyber Electromagnetic Activities (CEMA) to produce realistic effects for the training audience. However, incorporating EMS elements in training environments is difficult due to regulations on spectrum interference and the lack of integration with existing constructive and virtual simulation systems. In this work, we describe our initial efforts to provide an architecture to coordinate training of EMS operations and effects between the synthetic training environment and live training participants. We established an architecture, toolset, and approach to communicate threat radio jamming effects from the simulated environment, producing actual jamming effects on participant radios in the live environment. The Cyberspace Battlefield Operating System Simulation (CyberBOSS) system was used as an integrating architecture between simulated jammers in the One Semi-Automated Forces (OneSAF) system, stimulating software defined radios (SDR) in the live environment. This resulted in actual jamming effects on tactical radios instrumented with Direct Injection Jammer (DIJ) devices, providing an emulated jamming effect without any open-air jamming in the operational environment. This paper describes the work to date for this effort, and discusses the next steps to be taken to further coordinate CEMA training between live and synthetic training environments.

Drone Control to Major Tom: Anomaly Detection and Digital Twins

Eeshaan Verma

22166

As technology has improved, the use of drones has become commonplace, operating in a variety of domains from defence to environmental conservation. Among this are 'wingman' drones that are controlled by the pilot of an escorting vehicle. Their operational environment is often extreme and hence malfunctions can occur mid-flight which can vary from minor deviations in flight path to catastrophic failures. Dealing with these errors can lead to pilot overload and reduced situational awareness, especially within a complex domain such as congested or contested airspace. How does one predict the emergence of these faults and take action to mitigate them mid-flight autonomously?

Anomaly detection techniques allow for the identification of abnormal patterns within data and has been used for predictive maintenance. Generally, these techniques are trained on an ideal flight and sensor datasets which can be quite difficult to obtain. With the advent of the 4th industrial revolution, the boundaries between the physical and digital world have become blurred with technologies such as digital twins which can represent a physical system digitally.

This paper investigates using a drone digital twin and anomaly detection concurrently to predict and mitigate in-flight drone malfunctions. This will be demonstrated by the creation of a training dataset for anomaly detection

techniques using a digital twin, the comparison of new anomalous data with past malfunction patterns and the use of the digital twin to inform mitigation strategies, both in training and operationally.

Human Mobility 2049 – It's Time to "ACTT" (Aeronautical Conceptualization for Tomorrow's Transportation)

Kevin Hulme, Ph.D., CMSP

22174

Mobility (of people, goods, services) is an urgent, cross-disciplinary, bipartisan concern that impacts all humans on this planet. As our surface infrastructure continues to devolve (e.g., through overuse, congestion, and disrepair), intermodal Transportation has become a matter of extreme National priority. Recent emphasis is so pervasive that Federal policymakers are mandating widespread change, including the recent "Build Back Better" initiative. Near-term technological pathways towards improving human mobility include connected and autonomous vehicles (CAV's) and unmanned aerial vehicles (UAV's). Longer-term, domain experts are already investigating disruptive, bleeding edge prospects, including extreme advances with High-speed Rail, the Hyperloop, and even "flying car" technologies – formally referred to as Advanced Air Mobility (AAM). For such technologies, Modeling & Simulation (M&S) will be essential both to demonstrate baseline technological viability and to achieve long-term sustainability.

The 2022 I/ITSEC edict to ACTT! (Accelerate Change by Transforming Training!) is timely -- to enable humankind to revolutionize innovations that will overcome the varied Mobility challenges we face in the near future. This paper presents a notional examination of planned and ongoing Simulation developments towards realization of AAM on a broader scale. The proposed strategic vision is to urgently "ACTT": Aeronautical Conceptualization for Tomorrow's Transportation - through the rigorous and integrated application of M&S, and the Live-Virtual-Constructive (LVC) taxonomy. Our implementation includes: a) Live prototyping, using drones and quadcopters within a large testing enclosure; b) Virtual simulation, by way of a custom-designed, parameterizable ""human-in-the-loop"" Mixed Reality Flying Car simulator; and c) Constructive modeling, to enable vehicle traffic simulation into the third dimension through emulation of organic system behavior, including particle swarm theory. Critically, the paper concludes with an examination of candidate AAM Use Cases that will both: a) impact near-term human-machine interactions with next-generation mobility vehicles, and b) influence longer-term future urban development and planning.

Geospatial Data Pipelines for Urban Digital Twin Applications

Joanna Hobbins, Nick Giannias, Melisa Kopan; Simon Merrick, Ralph Coleman, Sean Lilley, Shehzan Mohammed

22180

Digital twins have become an important means of offering actionable insight into our world. The existing and potential applications are extremely broad in scope and drive a need for rapid creation of large scale digital replications of the real world.

We organize our digital twin application around four conceptual categories or "layers": Physical, Human, Resource and Cognitive. The Physical layer represents the world "as-built" and can include imagery, terrain and 3D models. The Human layer includes the population and their location, either through simulated pattern of life or real time geolocation feeds. The Cognitive layer encapsulates human awareness, behaviour, decision making, social connections and communication. The Resource layer contains the assets available for planning and simulation.

This paper reports on the design, implementation and integration of the geospatial data used to create the Physical and Human layers of one such digital twin, the city of London. Our project made extensive use of both cloud technology and open standards from the Open Geospatial Consortium (OGC). We faced multiple challenges related to: (i) the conversion of large amounts of photogrammetry data for streaming using the OGC 3DTiles standard (ii) the sourcing and processing of sufficiently detailed data for pattern of life and power network simulations and (iii) the performance challenges associated with using OGC WMS/WFS for real-time simulation.

Viewed individually, none of the challenges we faced are unique in the geospatial and simulation communities. However, we believe the intersection of the two domains and the lessons learned from our requirement to integrate data across the four "layers" may provide insight to others planning their own urban digital twins.

Context-aware and Perceptually Realistic Synthetic Wrapping for Military Training and Exercises

Olaf Visker, Annemarie Burger, Anne Merel Sternheim, Ruben Smelik, Remco van der Meer

22189

Armed Forces must constantly be ready for deployment in both national and international operations. Large-scale exercises ensure that different forces learn to co-operate, work together as a team, and maintain a level of preparedness. There are however limitations to the level on which exercises can be performed. Lack of available personnel, material, specific capacities and insufficient space and budgets result in difficulties with performing exercises with higher echelons involved. Even for small-scale training events similar difficulties can occur, especially when team collaboration is required. To be cost-effective and simultaneously meet training goals, training often requires a mix of live, virtual, and constructive simulations (LVC). Synthetic wrapping is a form of LVC simulation that enriches training through virtual and constructive simulation. Simulated units that participate autonomously in live exercises and training modules need to be able to communicate with the primary training audience, behave perceptually realistic, and contribute to the learning goal.

This research aims to explore a variety of Artificial Intelligence techniques in the context of creating perceptually realistic synthetically wrapped units. It focuses on three different domains: (i) communication via natural language, (ii) understanding the environment, and (iii) adaptive behavior. We present a synthetic-wrapping framework, and we show it working on a representative use-case: Joint Terminal Attack Controller (JTAC) training. In the use-case, the JTAC requests Close Air Support (CAS) from a simulated fighter pilot and guides the pilot towards a target. The proposed framework successfully supports the use-case and supports adaptive behavior based on the environment and natural interaction with a simulated unit. Our results show that modern Artificial Intelligence techniques can aid in the creation of perceptually realistic simulated units that allow for believable interactions and behaviors during military training and exercises.

Development and Validation of a Rapid Threat Assessment Simulation

Nickolas Vlahopoulos, Syed Mohammad, Ph.D., Sungmin Lee, Geng Zhang

22207

A new capability for Rapid Threat Assessment (RTA) due to explosive threats is presented. The audience for the new capability are non-technical users who need such information for planning. The RTA determines the maximum pressure load applied on building structures from an explosion in an urban environment and the lethal regions inside an enclosed space from the detonation of a threat that combines an explosive and projectiles. The former functionality considers a few alternative layouts for the urban environment and allows a user to select the type of layout, the main dimensions of the layout, the size of the explosive and its relative placement with respect to the buildings. This information is used for determining the level of blast worthiness that the buildings must exhibit in order to avoid catastrophic damage or the level of expected damage from an explosion. A Machine Learning (ML) approach is used for creating the answer for the maximum pressure load from a large number of high fidelity simulations that have been computed for each layout. The main dimensions of each layout, the size of the explosive, and its relative placement varied in each simulation. The results are used for training a ML model which is then utilized for predictions within the RTA tool. Simulation results are validated through comparison to published test data for two urban configurations. The second functionality of the RTA utilizes semi-empirical expressions for determining the initial velocity of the projectiles and a numerical solution to a system of ordinary differential equations for determining their trajectories. The lethality of the projectiles is determined from their velocity and their trajectory time histories. The lethal region from

the blast pressure is based on semi-empirical equations for peak pressure loads. The theoretical background, the validation, and the value of the RTA capability are presented.

Simulation for Security Force Assistance Climate Adaptation Training

Neil Sleevi, Howard Lee, Melvin Cape

22215

This paper proposes an innovative methodology used by Security Force Assistance (SFA) planners to leverage a sociocultural simulation for exploring climate change dynamics in Army training. This approach was derived from lessons learned during unclassified Joint exercises associated with the simulation of climate adaptation. According to President Biden's Interim National Security Strategy climate change poses a growing threat to U.S. national security. This strategy and the 2022 Army Climate Strategy make it imperative for Army operational and strategic exercises to include climate change risks and threats by 2028. The Army's use of simulation for training of its SFA forces will enable more effective planning for humanitarian assistance and counterinsurgency missions, especially those dealing with emerging requirements for adapting to climate change. Simulation in the field of climate adaptation training to support SFA in humanitarian assistance tasks and improving understanding of emergent counterinsurgencies is critically important to the U.S. military because it can lead to increased stability in developing areas of the world. The Army SFA Proponent and TRADOC G-2 M&S will leverage recent unclassified exercise results to demonstrate how simulation can support Joint and Army training for SFA Climate Adaptation Training in representative "battleground areas" and show what quantitative benefits might accrue for better understanding climate adaptation. This simulation approach may support other equities besides DOD including supporting U.S. Allies and partners by providing technical assistance, advice, and training to military personnel. Additionally, it may assist stakeholders such as non-governmental and private sector entities who need to be prepared for the aftermath of more frequent and severe extreme weather events. In this paper, the authors argue that the Army will be a more resilient and sustainable land force, able to operate in all domains with effective mitigation and adaptation measures against the key effects of climate change.

Driving Vehicle Maintenance Decisions using Predictive and Prognostic Maintenance Technology

Diana Perera, Kyle Whirlow, Timothy Whalen, Claire Hughes, James Cooper

22233

In 2022, the U.S. Department of Defense requested a $3.5 billion budget for depot operations and maintenance which includes critical repairs to aircraft, missiles, aircraft carriers, ships, submarines, combat vehicles, and other equipment. However, the actual approved budget ($2.1 billion) falls far behind what is needed, threatening the readiness of military vehicles. One way to close this gap is to employ predictive and prognostic maintenance (PPMx). The U.S. Department of Defense has already prioritized a shift to PPMx solutions as the technology has been proven to optimize standard maintenance scheduling and reduce time, expense, and downtime due to component failure, repairs, and replacements across industries. This approach continues to grow in its usefulness as more powerful ML techniques and greater amounts of data are collected and able to be easily stored. Now that the technology is mature, there is a need to determine which predictive modeling approaches are best suited to military vehicle maintenance.

This paper details research to identify effective approaches for predictive models for vehicle maintenance utilizing a combination of onboard sensor data, historical and peer vehicle data, and maintainer input for PPMx. This includes a comprehensive review of statistical and ML modeling approaches used for vehicle PPMx, with a focus on anomaly detection, fault classification, and remaining useful life estimates from survival regression models. Finally, a case study is presented demonstrating the way these approaches could be applied to U.S. Army vehicle operations and maintenance. Specifically, opportunities and constraints regarding available data and systems are considered, focusing on technical considerations for a human-in-the-loop approach to integrate maintainer feedback into the predictions and decision support recommendations produced by statistical models. This integrated approach can provide more effective and holistic PPMx solutions to help drive vehicle maintenance decisions, reduce costs, and increase readiness in the U.S. military.

Using Agent-Based Modeling and Simulation to Evaluate Collision Avoidance in UAS Swarms

Luis Osegueda, Mustafa Akbas

22234

With a rise in the use of Unmanned Aerial Systems (UAS) across a variety of industries comes a rise in the concern for safety. Many available platforms nowadays come equipped with obstacle detection and collision avoidance systems. Systems such as these are often used for the creation of drone swarm platforms to better handle certain situations such as scanning a large area or increasing their coverage in a three-dimensional space. This paper explores the use of agent-based simulation to evaluate the characteristics and behaviors of collision avoidance for UAS swarms. The paper also explores the outcomes of allowing individual UAVs within a swarm to navigate semi-independently when an obstacle is detected and return to the swarm when a collision state is successfully prevented. Through the use of a scalable agent-based modeling approach, different swarm formation algorithms are modeled along with obstacles along the swarm's flight path. Along with a view into the swarm's collision avoidance behavior when an obstacle is encountered, unique differences can be seen in the characteristics of different formations. The formations modeled for the purposes of this paper include "follow the leader UAS", a horizontal "scan line", a 3D cube, and a virtual forces formation. The performance characteristics that are investigated include the time to build the formation as well as the success rate for avoiding a collision. The model developed for this paper can be adapted to account for new formation algorithms as well as different collision avoidance algorithms in the future for finding an adequate solution for a given application.

An Immersive Content Creation Pipeline for Information Age Training

Deepak Haste, Sudipto Ghoshal, Valarie Yerdon, Maartje Hidalgo, Jeffrey Beaubien, Ph.D., Jason Wong

22242

Commercial Off the Shelf (COTS) Augmented Reality and Virtual Reality (AR/VR) technologies are increasingly finding their way into DoD maintenance training because of their ability to support hands-free, just-in-time (JIT) training and troubleshooting. In addition, these technologies reduce the need for physical training assets, thereby allowing learners to practice at their home station, rather than traveling to a dedicated training facility. A major impediment to the broad adoption of AR/VR training has been the advanced design and programming skills that are required to generate 3D content. Historically, the reuse and transformation of legacy maintenance training materials into immersive training content has been a time-consuming, manually-intensive process.

In this paper, we present an automated content creation pipeline that uses open source tools to convert legacy training content into interactive and immersive 3D content. We lay down an approach to automate this pipeline, thereby minimizing the number of steps required to convert the source material into usable 3D content. The content creation pipeline does not require any specialized AR/VR design and programming skills, thereby providing instructors full control over the content generation process via an intuitive immersive scene editor. The resulting 3D objects can be managed in libraries and subsequently reused multiple times.

This paper will also aim to define the scope of legacy training content and prioritize which conversions to develop based on required effort and the prevalence of legacy content. Finally, we conclude with the results of a U.S. Marine Corps training schoolhouse survey that identifies the most prevalent legacy content types that are candidates for conversion, as well as the required effort and efficiency of each conversion process. The paper concludes with best practices and lessons learned so that the reader can implement these content conversion practices in their own work.

Streamlining Point Cloud Post-Processing Using Principal Component Variance, Distribution Evaluation, and Other Statistical Metrics

Michael Holm, Jack Miller, Eliot Winer, Ph.D., Adam Kohl

22257

The 3D scanning market is predicted to rise by 10.2% annually through 2026 to a market size of nearly 11 billion dollars. Additionally, in 2018, it was reported that the U.S. Navy saved nearly $2 million on a project by pursuing 3D scanning technologies. These scanners allow the modeling and simulation community to create digital representations of landscapes, vehicles, or other legacy objects for a variety of uses such as virtual training environments. While the use of 3D scanning is growing, problems with the technology still exist, such as erroneous data capture due to overexposure or overly dense sampling. These issues result in point clouds that are unwieldy and challenging to use. Current post-processing techniques for point clouds often require a "guess and check" method of determining proper parameters for cleaning unwanted points or reducing (i.e., downsampling) the number of points in the cloud. This takes a high number of iterations, and significant time to produce a usable point cloud model.

This paper presents a workflow with the purpose of reducing point cloud noise and generating a clean model quickly and efficiently. Using open-source libraries, the potential of mathematically determining suitable parameters for operations performed on point clouds, such as noise filters, was investigated. The outcomes of this research present the relationships between common point cloud post-processing operations and standard point cloud metrics, such as principal component variance and total file size. Determining existing relationships for these parameters allows a post-processing workflow that removes the need for multiple iterations. The resulting workflow was applied to several models and was significantly faster in processing time than traditional iterative processes and produced smaller models in points and file size. Analysis of the results also showed potential for automating this process in future work to further ease these post-processing activities.

Creating Common Ground: The Impact of Terrain on Distributed Mission Operations

Emilie Reitz, Kevin Seavey, Marcus Young, Leonas Venckus, Justin Wright

22273

U.S. Special Operations Command (USSOCOM) is committed to providing its Service Component and Sub-Unified Command Commanders a distributed synthetic environment that enables distributed mission training, exercises, and no notice/short notice mission rehearsal.

In late 2016, the Under Secretary of Defense for Acquisition, Training, and Logistics (USD AT&L) and USSOCOM began an effort to improve Modeling and Simulation (M&S) systems interoperability that resulted in several standardization focus areas. One of these areas involved the National Geospatial Intelligence Agency (NGA) launching a wide-reaching project focused on the Open Geospatial Consortium's Common Database (CDB) as the standard for M&S geospatial data support. USSOCOM J3-T&E, assisted by Joint Staff (JS) J6, was tasked to assess the NGA-CDB capability in a USOCOM distributed training context, collecting and providing metrics to show improvement opportunities capitalized using this new terrain capability.

Bold Quest (BQ) 21.1 was the venue for this assessment. Occurring from 26 July to 12 August 2021, BQ21.1 included all USSOCOM components and the Joint Special Operations Command, the U.S. Army, and the Air National Guard. BQ21.1's primary objective was to assess the interoperability of using NGA-CDB, including the Foundation Geospatial Intelligence (GEOINT) Three Dimensional (FG3D) capability, and create run-time databases for the primary USSOCOM simulators. The secondary objective was to support the development of USSOCOM's distributed training and mission rehearsal capabilities across its components. This paper describes the impact of using CDB-based terrain data on simulator interoperability and lessons learned about the process of creating a multi-component synthetic environment.

Human Behavior Models for Adaptive Training in Mixed Human-Agent Training Environments

Joost van Oijen

22287

Current trends in simulation-based military training show an increasing demand for artificial intelligence (AI) and data science technologies to offer more flexible and adaptive training solutions for military personnel in rich simulated training environments. This requires technologies capable of (1) measuring and assessing performance of trainees in real-time, and (2) simulating role-playing agents that can replace human role-players, and adapt their behavior to guide learning experiences for a trainee.

The above requirements pose two challenges. First, current training systems often lack an understanding of the dynamic context of a trainee's behavior, which is required to judge its performance during training of specific missions, (part-)tasks or tactical situations. This context is typically only available in the head of an observing instructor. Second, behavior models for simulated role-players are often black boxes from the point of view of an instructional system and cannot easily be adapted for instructional purposes (e.g. exhibiting degraded performance or making deliberate mistakes).

In this paper we present a unified human behavior modelling (HBM) approach that addresses the above challenges. It is based on the idea that HBMs can be used to model roles for both human trainees and agents. For an agent, it acts as an AI model that produces behavior, equipped with predetermined adaptive variables. For a trainee, it acts as an observer that tracks, measures and assesses behavior being performed by a trainee. The HBMs (1) support instructor-based and automated tutoring, (2) promote collaborative design of instructional systems between training designers, subject-matter experts and behavior modellers, and (3) allow for interchangeable roles in training.

We demonstrate a proof-of-concept of the HBM approach in the scope of a training system for military aircrew training. Several use cases for adaptive training for fighter pilots are addressed and based on an implementation, challenges and lessons learned are discussed.

Dr. Strangemodel: Assessing Model Based Systems Engineering (MBSE) in the U.S. Air Force Simulator Common Architecture Requirements and Standards (SCARS) Initiative – the Way Forward

William Riggs, George Ayers, Joseph Doak, Austin Abraham

22293

The US Air Force Simulator Common Architecture Requirements and Standards (SCARS) Initiative is spearheading the employment of digital engineering principles for the design, development, sustainment, and upgrade of Air Force training systems. The SCARS digital engineering strategy includes the creation of an Operational Training and Test Infrastructure Enterprise System Model (OTTI-ESM) and a Government Reference Architecture (GRA) for simulators that captures common structures, interfaces, and behaviors in compliance with the WNS Model Based Systems Engineering (MBSE) style guide, based on the Systems Modeling Language (SysML). This style guide prescribes general rules for SysML models as well as specific conventions for engineering analysis, requirements tables, structure and behavior diagrams.

Because multiple government, industry, and military stakeholders contribute to the OTTI-ESM through construction of training system models used by SCARS, a consistent approach to evaluating SysML products is essential to the achievement of consistent modular openness and usability of MBSE artifacts. This paper will discuss various methodologies used to assess Modular Open Systems Approach in a system of systems context, SCARS evaluation methodologies and potential improvements in architectural metrics as applicable to evolving simulation architectures in a cyber-secure, cloud based environment. Both qualitative and quantitative methodologies are discussed, including the use of tiger team and peer review processes employed by the SCARS Engineering Capabilities Board and the AFLCMC/WNS MBSE team in conjunction with the SCARS Prime contractor, Partners, and Affiliates. The applicability of attribute-driven design principles to SCARS Reference Architecture development will also be discussed in conjunction with accessible tools and metrics. This paper provides examples of the methodologies used results achieved to date, lessons learned and proposed enhancements for the future.

The Software-Based Cyber-Physical Interface for ICS/SCADA: Delivering High Quality Cyber Training, Testing, and Mission Rehearsal using Gaming Interfaces

Scott Thompson, Rembrandt Bukowski

22299

Cyber training, testing, and mission rehearsal for Operational Technology (OT) is quite different than traditional IT because physical representations of an industrial process (known as a cyber-physical interface) are needed to convey the status of an Industrial Control System (ICS). Cyber-physical interfaces are quite challenging for organizations to build. Industrial equipment is expensive and requires a lot of floor space, demanding high costs for the initial build and reoccurring costs associated with leased facilities. Large cyber-physical interfaces demand dedicated workers to maintain them and require routine and corrective maintenance. High-energy systems present significant safety challenges. Users often need to travel to the site of the cyber-physical interface, increasing travel costs and presenting roadblocks when travel is restricted because of pandemic concerns.

These challenges can be addressed by offering cybersecurity researchers and trainees with a completely software-based cyber-physical interface that provides a visualization of physical process and reacts in a realistic manner to changes in the ICS/SCADA system.

A software-based cyber-physical interface is a scalable, modular platform that offers users the ability to model environments as small or as large as they desire. Training or testing audiences can be anywhere in the world, remotely connected with the ICS/SCADA environment and seeing the impact of cyber effects against cyber-physical systems using a web-based video feed served by the software. Software-based cyber-physical interfaces provide an engaging, immersive experience for the user through vivid and realistic representations of physical systems that can be delivered through 3D video or through AR/VR headsets. The software-based nature of the system allows organizations to deliver cost-effective remote training, testing, or mission rehearsals when travel is restricted by COVID-19.

Cybernetic Distortion: Training in an Uncanny Virtual World

Brian Flowers, Summer Rebensky, Ph.D., Michael Keeney, Jeffrey Beaubien, Ph.D.

22302

Virtual reality (VR) training systems can provide consistent, repeatable, on-demand, cost-effective, and safe environments for operations in stressful high-risk tasks. However, an unrecognized risk to the value of VR training is cybernetic distortion, which occurs when VR is not sufficiently representative of relevant factors in the real-world environment, particularly with respect to visual perception, proprioception, vestibular response, ergonomics, and information perception. Cybernetic distortion can occur when validation efforts in VR training focus on how the training presents technical content but does not assess all relevant cybernetic characteristics. VR training provides a wealth of data and interactions within a simulated environment, but distortions in the human-machine-interface alter how users understand, adapt to, and make use of this information in imperceivable ways. Without a holistic cross-over validation between real-world and virtual conditions, cybernetic distortion can lead to well-practiced behaviors that are correct only within the simulation (commonly referred to as negative training). In the real-world, these automatized behaviors practiced in unrepresentative VR training could lead to catastrophic outcomes in high-risk situations. While many of these distortions can be mitigated through targeted environmental design or hardware selection, potential negative training effects must be understood and characterized, so that they can be identified and minimized before deployment. While the impetus for these effects can seem minor (user discomfort, visual perceptual alteration, misalignment between the real-world and virtual environments, misaligned ergonomic considerations, and workflow alterations), each of them could have a unique, additive, or multiplicative disruptive effects on training transfer. This paper will discuss the current use cases of VR training, perceptual and ergonomic concerns in VR not reported in simulation research, how these issues could impact training validity, and known mitigations for these issues.

Adversarial Scene Generation for Virtual Validation of Off-Road Autonomous Vehicles

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22306

Perception models based on machine learning and deep neural networks are susceptible to misclassifications from subtle perturbations to their inputs. This is concerning because on-road autonomous vehicles (AVs) encounter a variety of perturbations that arise from uncertainty due to the unpredictable behaviors of other actors. Off-road AVs face even greater uncertainty due to the large variation in natural, unstructured environments. Numerous AV simulation tools and algorithms have been created to efficiently explore (and even improve) the robustness of machine learning algorithms for on-road AVs, however, only a handful of tools have demonstrated usefulness for the off-road domain.

This paper presents a modeling and simulation approach for generating adversarial scenes for off-road AVs using reinforcement learning. By "adversarial" we mean that the scene is (ideally) maximally problematic to navigate by the vehicle's autonomy system while constrained to be realistic. Our work consists of three components: a high-fidelity simulation platform, an adversarial scene generator, and an autonomy system under test. The simulation platform is designed using Unreal Engine 4 and uses a custom plugin to enable users to automatically create basic off-road scenes (e.g., flat ground plane) and run various navigation scenarios. The adversarial scene generator (ASG) uses a distributed Twin Delayed Deep Deterministic Policy Gradient algorithm with prioritized experience replay and a novel action saturation penalty to create test scenarios. The example autonomy system under test has a perception system with a U-Net architecture to predict traversable regions from camera images and uses an A* path planner to avoid the non-traversable regions.

We present results that demonstrate that the ASG architecture can generate pathological scenes on a flat ground plane with up to 32 obstacles. We present studies that highlight various features of the generated scenarios and their implications, and finally we conclude with limitations and future work.

Modeling Fuel Replenishment Logistics and Impacts of Alternative Synthetic Fuels

Brant Horio, Stephanie Brown, Lucas McCabe, Simon Whittle, Michael Anderson, Chris Johnson, Stuart Funk

22316

A critical factor for deterrence and any protracted conflict, is the ability to resupply our forces to maintain extended physical presence, which includes an ability to sustain naval air operations in remote areas. Successfully doing so must also minimize dependency on long-distance transport of fuel across oceans and be resilient to disruption of our fuel supply chain and operation of our fuel distribution facilities. This is a nontrivial logistics challenge as fuel replenishment logistics operate within a highly dynamic and interconnected system of combatants, auxiliaries, and fuel supply points, each with specific processes and behaviors that define how they interact with each other. Current logistics for replenishment of conventional aviation fuel have hard constraints that limit scale (e.g., limited fuel tanker resources) and subject to risk of potential cascading impacts due to disruption at strategic fuel supply points (e.g., calls for the Red Hill facility to halt operations due to groundwater contamination concerns). Toward these risks, ongoing research into alternative fuel sources for sustainable aviation fuel—following the motto, produce it when and where you need it—have increasing importance to national security. Advancing technology for scalable and mobile production of synthetic aviation fuel from alternative sources, such as seawater, promises to redefine naval replenishment logistics. While engineering challenges to make these technologies fully scalable are making progress, the operational feasibility of the adapted logistics must be fully understood. In this paper, we examine the system through a complexity lens and use agent-based simulation to develop an experiment platform to evaluate operational and environmental impacts over a range of scenarios. We propose this approach as useful for establishing relevant baselines, quantifying operational feasibility, providing guidance for the engineering teams, and ultimately characterizing the value proposition of synthetic aviation fuel for naval logistics. Finally, we discuss possible applications (e.g., wargaming).

Human Fatigue Modeling in Wargaming Simulations

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22331

Wargaming is a valuable tool for military planning, leadership strategic thinking, and tactics training. However, wargaming simulation software has critical limitations that need addressing to increase the realism and efficacy of the scenarios. One limitation is that human factors are often absent in scenarios, with personnel treated as high functioning, undifferentiated units. In reality, human factors have critical effects on personnel readiness and performance. Of particular interest in the current effort are the effects of human fatigue on simulated personnel entities and how this can inform wargaming participant decision making.

We developed an application that integrates human fatigue modeling with a wargaming logistics simulation to augment the system to include the effects of fatigue on aircrew and maintainer mission readiness and performance. The fatigue modeling application was developed using the R programming language Shiny package and implements the Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) biomathematical fatigue model. The SAFTE model produces performance effectiveness curves (i.e., fatigue) based on sleep input, homeostatic regulation, circadian rhythm, and sleep inertia. As a use case, the application intakes Air Tasking Order (ATO) information from the Integrated Sustainment Wargaming and Analysis Toolkit (iSWAT), which provides logistic resource information on aircrew and maintenance personnel, and other resources pertinent to wargaming scenarios. Sleep schedules for personnel were generated in the fatigue modeling application based on ATO information, general scheduling practices from the literature, and subject matter expert input. The current effort examines fatigue estimates based on a realistic, mock-up wargaming scenario.

Resulting fatigue estimates suggested that a subset of aircrew and maintainer schedules commonly generated fatigue during the wargame scenario, likely degrading performance and increasing safety risk. This has important implications for wargaming participant decision making as they will need to shift mission sets and use alternative resourcing to ensure peak mission readiness and performance.

Using One World Terrain in Live Training Exercises

Marwane Bahbaz, Tagg LeDuc, Julie Kent, Clayton Burford, Gage Jenners, Keith Nielsen

22345

As the Army moves to converge Live, Virtual, and Constructive simulation domains for the Synthetic Training Environment (STE), the need for One World Terrain (OWT) capabilities greatly increases. However, as more OWT standards, services and datasets evolve and mature, the focus now shifts more to terrain content in support of live training engagements which has implications on the terrain production strategy, representation of battlefield effects, and service availability at the point of need. In order to minimize fair fight issues such as improper hit adjudication or potential negative training outcomes, the digital terrain to real world approximation will require increased spatial, geometric, and semantic resolutions that exceed traditional virtual or constructive simulation needs. In the evolution of the STE for Live Training Systems (LTS), OWT will serve as the core authoritative terrain content that can then be further extended for the STE LTS use cases toward adjudicating and providing accurate battle damage assessment from simulated weapons engagements. The Army has a wide variety of weapons with associated penetration capabilities depending on the cover provided by the terrain. High fidelity terrain characteristics coupled with ballistic and effects models are necessary to simulate the effects of various weapons in multiple engagement scenarios. This paper presents initial experiences from the LTS community focused on hosting and delivering OWT services during live training exercises. This data will highlight areas where OWT capabilities can be augmented and extended to address live training integration challenges in the STE. Additionally, these experiences may support enhancements to geospatial data collection and distribution while encouraging developers to incorporate OWT capabilities into future training devices. This will promote wider community acceptance and further refinement of the OWT standards and architecture.

A Federated Multimodal Simulation Environment for Studying Interactions between Different Modes of Travel

Jacklin Stonewall, Michael Dorneich, Eliot Winer, Ph.D., Jack Miller, Vijay Kalivarapu, Adam Kohl, Stephen Gilbert, Anuj Sharma

22361

In 2013, congestion cost the U.S. economy $124 billion, which is expected to reach $180 billion by 2030. Further, the societal cost of traffic crashes in the U.S. exceeds $900 billion each year. Extended reality (XR) and advanced traffic simulation technologies offer potential solutions to these issues by allowing complex roadway systems with mixtures of human and autonomous vehicles to be analyzed. As autonomous vehicle technology becomes more pervasive across the Department of Defense, simulation of such complex multimodal scenarios is critical. InterchangeSE facilitates this multimodal simulation in a risk-free environment. InterchangeSE allows a variety of complex simulated scenarios involving live and virtual participants (e.g., drivers, traffic managers, pedestrians, autonomous vehicles) to be authored and run in varying degrees of immersion.

This paper reports on a summative evaluation of InterchangeSE with both live and autonomous participants across multiple modes and environments. Environments are customizable using images from maps which are translated into 3D visuals via computer vision algorithms. Physical participants interact with each other and the environment using a variety of extended reality displays and input devices (e.g., stationary-mounted bicycle, car steering wheel). Driving parameters, such as position and heading, are synchronized with traffic (i.e., vehicles and pedestrians) and computed by a traffic simulator. The computed traffic is relayed back to participants, who adjust driving responses in real time. Metrics such as traffic violations and routes completed are used to determine a participant's performance while simulator sickness, presence, workload, usability, and efficacy are used to determine the system's acceptability and overall user experience. Results show high performance and overall user experience indicating InterchangeSE is a feasible option for simulating traffic management scenarios with a range of virtual and live participants. This represents an important step toward addressing the economic and social costs of traffic congestion and collisions.

Multi-agent Reinforcement Learning with a Scout Mission Scenario in RIDE

Volkan Ustun, Rajay Kumar, Lixing Liu, Nicholas Patitsas

22367

Until recently, most existing synthetic character behavioral models for military training simulations were either rule-based or reactive with minimal built-in intelligence. As a result, such models could not adapt to the characters' experiences, be they with other synthetic characters, the environment, or human trainees. Multi-agent Reinforcement Learning (MARL) models multiple agents that learn by dynamically interacting with an environment and each other, presenting opportunities to train adaptive models for both friendly and opposing forces to improve the quality of synthetic characters. Still, military environments present signifcant challenges since they can be stochastic, partially observable, nonstationary, and doctrine-based. This paper introduces a scout mission scenario modeled within the Rapid Integration and Development Environment (RIDE) on a geo-specific terrain designed to leverage deep learning and simulation-generated experiences in a MARL framework and presents results from exploratory experiments. Furthermore, it discusses the trade-offs between various design choices, including discrete versus continuous observation spaces and bootstrapping behavior policies with pre-trained models.

Real-time Simulation Executive Architecture and Subsystem Containerization

Zack Kirkendoll

22403

The design, development, and deployment of a containerized real-time simulation executive architecture for scheduling and executing high fidelity software system models poses many challenges. Both industry and the Department of Defense (DoD) are researching technologies and software platforms to provide efficiency and effectivity benefits through DevSecOps

and containerization. While DevSecOps has propagated toward the modeling and simulation industry, there are still significant obstacles to be addressed to support a systematic paradigm shift from the status quo.

Real-time simulation domains are rarely plug and play environments, especially for full-flight simulators. There are external aspects to include haptic, visual, kinetic, aural, and temporal characteristics. There are hard real-time considerations for preemptive task switching and sequencing, prioritization, jitter, and latency. There are typically services necessary for shared memory, semaphores, inter-process communications, and peripheral interfaces to include Ethernet, MIL-STD-1553, ARINC 429, Serial, standard I/O, and distributed training environments.

This paper evaluates these considerations within the applied domain of a real-time full-flight simulation executive architecture running high fidelity software system models within a containerized architecture. The simulation executive architecture runs on a Linux operating system with a real-time kernel patch. The real-time executive runs a collections of software modules scheduled and executed in a deterministic real-time fashion for the software-in-the-loop simulation. This executive architecture has been utilized for multiple DoD USAF flight simulators including Federal Aviation Administration (FAA) 14 CFR Part 60 Level D compliant systems requiring Security Content Automation Protocol (SCAP) compliance.

First, a review of industry and DoD activity as related to this concept model is decomposed. Second, the problem domain and challenges to its application are defined. Finally, a detailed open framework for implementing a containerized real-time simulation executive architecture and subsystems is provided. This is critical to enable system designers to achieve a successful deployment for a real flight simulation application.

Anomalous Responses to Highly Immersive Virtual Reality Displays

Angus Rupert, Ph.D., John Brill, Ph.D.

22405

Although rare, anomalous responses to highly immersive virtual reality (VR) displays can pose user challenges with disastrous consequences especially when operating motor vehicles/military platforms. Anomalous responses manifest frequently as unusual visual-vestibular or vestibular-spinal perceptual-motor effects to include non-veridical sensations of motion and balance disturbances. Examples include driving off the road following a long session in an aircraft simulator or prolonged balance dysfunction after strong vection experiences similar to the rare but often prolonged mal de debarquement balance issues following sea voyages. To investigate adverse effects on balance coordination associated with adaptation to a motion-based environment, subjects were seated in a 20 foot diameter rotating room that was slowly rotated while subjects performed controlled head movements in pitch and roll once per minute for periods of time varying from 10 to 30 minutes. When compared to baseline balance performance on the Equitest balance device all subjects demonstrated reduced performance scores following 20 minutes of exposure on the rotating room. Since the anomalous reactions are rare events, individual but well documented cases become important. The lead author exposed an individual to a highly compelling vection illusion as part of a demonstration of whole-field vection inside a rotating sphere. Shortly after exiting the sphere, the subject experienced balance dysfunction which was thereafter readily experienced with large field visual displays and only dissipated slowly over the following three years. Both the motion-based adaptation experiment and the controlled full-field vection experience produced visual-vestibular conflict adaptation issues that will become increasingly important especially as VR/AR devices become more visually compelling and are integrated with motion based devices or involve self-motion of the user. Based on lessons learned from adaptation to motion-based devices there are techniques that should be recommended to VR/ER software developers to reduce the frequency of potentially dangerous physiological and perceptual anomalous responses.

Simulated Cyber Analyst for Network Vulnerability Assessment

Ning Wang, Eric Holder

22408

Artificial intelligence (AI) is playing an increasingly important role in the Combatant Command Cyber Protection Team's (CCMD CPT) planning process. With petabytes of past cyber incident data available, AI can be a useful tool to understand the complex relationships within system components, vulnerabilities, threats, and implications on future missions. Since such AI often works alongside human cyber operators to support mission commanders in decision-making, the understanding of the AI's decisions and the rationale behind such decisions can be key to the success of this human-AI team. An analyst or operator often need to explain analysis by the AI to a commander when recommending course of actions. It is critical to make core decision factors, assumptions, uncertainties and the variables that drove the analysis accessible to the human.

In this project, we designed a simulated cyber analyst to advise mission planners on the target network systems in terms of what has happened (incidents, vulnerabilities, threat presence), likely follow-on adversary activities, and where to monitor, harden, or counteract those. We synthesized a dataset that include incident reports on past attacks on military networks. Various AI techniques with varied explainability were applied to analyze the dataset to determine vulnerabilities of a set of simulated target networks. We then developed a series of explanations algorithms for each AI techniques to explain the policies and how such policies are learned. Such explanations were fed into the simulated cyber analyst to justify its vulnerability analysis and recommendations on course of actions. The cyber analysis is placed in an experiment testbed with simulated target networks to study how such explanations impact human-automation team performance. In this paper, we will discuss our research into how transparency communication provided by AI in a simulated cyber analyst can impact human-AI teaming in cyber operations.

Autonomous Generation of Intelligent Patterns of Life

David Pynadath, Ali Jalal-Kamali

22409

To prepare soldiers for missions in densely populated environments, simulation-based training needs to immerse them in a similarly populated training environment. One challenge in simulating such an operationally realistic experience is re-creating the same patterns of life that the real population exhibits in response to alternative courses of action. The complexity of such behaviors and of their interdependency with military operations have motivated a need for AI methods that can generate realistically dynamic patterns of life. Unfortunately, most existing behavior-generation approaches rely on manual scripting of patterns of life, with insufficient flexibility to support the "free thinking" that real-world civilian populations exhibit on a daily basis. We have instead applied a multiagent social-simulation framework, PsychSim, for autonomous behavior generation for individuals and groups, across the range of socio-cultural backgrounds relevant to a simulated operating environment. PsychSim provides reusable mechanisms for the cross-cultural decision-making that forms the basis for the patterns of life implemented in this work (e.g., an individual may choose a route to work that avoids the site of a recent firefight, a crowd of civilians may decide to cheer or protest a blue-force unit's actions). We use decision-theoretic agents to choose the behavior they think best advances their goals. Unlike typical agent-based social simulation, the agents' behavior will not be determined by manually authored rules. Instead, the agents will form perceptions of their current situation, their current options, and the relative desirability of those options in terms of their expected outcomes. The agents will thus be sufficiently free-thinking to respond in a robust way to whatever situation they find themselves in, regardless of what path the human behaviors or exogenous events have taken the scenario. We illustrate how this underlying foundation can support a variety of relevant patterns of life taken from operationally relevant scenarios.

Leveraging Parallel Processing to Accelerate Large-Scale Simulations on GPUs

Brad Suchoski, Heidi Gurung, Steve Stage, Sid Baccam

22448

Simulations, data analysis, and artificial intelligence (AI) can be computationally intensive, but you don't necessarily need a supercomputer to tackle your problems. Initially designed to make video games look better, graphics processing units (GPUs) are now being used for powerful research. Our presentation will provide background on the key differences between GPUs and traditional central processing units (CPUs), describe different types of

problems that are best (and worst) performance-wise for each processor, and give examples of our own work with GPU processing. Our first example is source term reconstruction, where we use sensor and weather data to calculate the most likely release location, quantity, and duration. We will also discuss how we use GPU processing with a Markov Chain Monte Carlo (MCMC) method to tackle problems that were previously thought to be too computationally intensive and slow. We use the MCMC technique to develop complex epidemiological models that provide projections for future COVID-19 cases and deaths to help decision makers. Our projections are done for approximately 400 jurisdictions, running 4 million simulations per jurisdiction, our GPU MCMC technique completes approximately 1.6 billion simulations in under 45 minutes using a developer's workstation. Finally, we coded a GPU implementation of a plume dispersion model. Running on a single-threaded CPU, 300,000 plume simulations were completed in 319 seconds. Executing 12 million plume simulations on 4 GPUs was completed in 52 seconds, approximately 247 times faster than the single-threaded CPU solution. While GPUs are not a silver bullet that can solve all problems faster, we discuss the types of problems that are suitable for GPU processing in the hope of inspiring others to use this technology to solve challenging problems.

LOD and Texture Mapping for Real-Time Radar Ground Map Simulation

Radu Visina, Jameson Bergin, David Kirk, Peter Skangos

22449

Modern radar simulation techniques can be used to generate artificial, yet fully realistic, radar sensor outputs such as Synthetic Aperture (SAR) and Real Beam (RB) ground map images. In general, when simulating the effect of an external channel, a numerical electromagnetic solver should have 3D models of the scene it is looking at. The creation of these scene models, as well as the rendering of radar images (using rasterization and/or ray tracing), parallels the developments and techniques of modern computer graphics (CG) systems. While CG techniques have mostly focused on the simulation of optical cameras, the physics of RF microwaves and radar signal processors means that simulation of a radar RF receiver requires unique, innovative techniques. Two fundamental differences between radar and optical systems are: information in the down-range dimension of radar data comes from range instead of perspective projection; and radar receiver data requires complex phase coherency, whereas conventional CG algorithms assume incoherent waves. In wide-area radar ground map images, features such as buildings and ground vehicles can be seen as strong returns from certain angles, but it is computationally impractical to use highly detailed mesh models for every scatterer in a scene. This paper reviews and adapts the modern CG techniques of Level-of-Detail (LOD) and Texture Mapping (including normal and tangent maps) to solve radar-specific simulation problems that increase the visual accuracy of the rendered images and decrease the time required to render. The improvements that are achieved with these techniques are of immense value for mission planning, radar scope interpretation training, and for the generation of synthetically generated training data for machine learning systems.

Sensor Fuzed Munition Modeling Framework

Cesar Sosa, Antonio Aguirre

22485

A modeling and simulation framework, exclusively for sensor-fuzed munitions, has been developed to assess whole system and sub-system performance with respect to various terrains, meteorological conditions, target types, and weapon-target engagement dynamics. The framework supports simulation of complex terrain and target geometries and thermal signatures, lethal search, and target acquisition, engagement, and lethal effects. Most importantly, the framework enables a rapid prototyping and developmental environment by providing strategic simulation breakpoints for recycling data and hot-swapping sub-system models. This unique modeling framework was made possible by identifying and forging together existing methodologies and models from multiple different disciplines, programming languages, and levels of fidelity. To date, the framework and data products, to be presented, continue to be critical for answering sensor-fuzed munition system performance questions across multiple US ARMY programs. Regular data products include kill-chain performance probabilities and target hitpoint maps. Additionally, the framework includes custom tools for conducting data analysis for tracking system performance against defined requirements, providing insight into performance sensitivities, and enable design choices and down selections to be well informed. Current efforts are focused on statistical based design of experiment techniques, model fitting, and predictive analytics. This documentation will focus on the framework design, data products, and analysis tools.

TRAINING

BEST PAPER

VR Training System for Rehabilitation and Compensatory Analysis after Stroke

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22325

Stroke is one of the most common diseases that lead to impairment of upper limb dexterity. Nowadays, Serious Games is a common approach to help stroke patient's recovery. However, during motor rehabilitation protocols, it is important to detect compensatory movements, which are not currently handle in most serious games. The lack of compensatory movement detection can lead the patient to learn new and incorrect movement patterns, compromising training sessions. Thus, this paper presents a novelty technique that differentiates real upper limb functional improvements from compensatory movement patterns. To prove our theory, a system has been developed. This system consists of a highly customizable Virtual Reality serious game, with adaptable levels and tasks. Interaction with the game is done through a handle of a robotic platform. This platform has assistance feedback, which can be configured to stimulate or restrict the execution of the movements. In the game, the patient has to control a harpy to hunt and to run from predators. Inertial sensors are placed in different points of the patient paretic arm. Through these sensors, it is possible to detect a compensatory movement and to lead back the patient to correctly guide the harpy. A three-dimensional biomechanical model for musculoskeletal simulation was also developed. This model allows the simulation and analysis of muscle activity associated with movements, as well as the analysis of the kinematic synergy of the limbs, captured during the execution of training sessions. Therefore, we believe that the proposed method along with the built VR serious game system will be a useful supporting tool for helping both the patient during his training sessions and the therapist for better analysis of movements in conjunction with the definition of more specific stroke rehabilitation protocols.

Machine Learning Aids Targeted Guidance to Trainee's Decision Making Performance

Quinn Kennedy, Peter Nesbitt

22102

Background: Identifying the conditions, doctrinal concepts and specific trainee actions underlying decision performance assists military trainers in applying limited intervention resources. We explore whether a machine learning approach to human decision learning process can provide targeted intervention guidance. Consequential Learning Assessment (CLA) measures the trainees' ability to sense the state of the environment and take actions that minimize tactical risk without explicit instruction.

Method: We applied the CLA to a computer-based platoon formation decision making task (PFDT), which includes 32 scenarios randomly presented four times (n = 128 trials). For each scenario, there was an optimal, acceptable, or poor decision response. This study was approved by the NPS IRB. Thirty participants (11 female) with no prior experience in leading troops in dismounted infantry operations completed the PFDT. We modeled participants as decision agents in a sequence of decisions in which previous decision(s) should inform the current decision. We then examined whether CLA results

varied by scenario factor (time of day, terrain height, terrain vegetation, enemy direction, and enemy likelihood) as a measure of learning, defined as the percent of trials on which optimal exploration or optimal exploitation occurred.

Results: Application of CLA to the PFDT data revealed over 75% of all decisions resulted in optimal behavior across scenario factors and supports learning-focused agent assessment. The presence of low light conditions or enemy direction to the front each resulted in 10% more optimal decisions across all participants. This type of learning trend across the cohort offers insight on delivery success of factor specific training.

Conclusion: Preliminary results suggest that application of CLA can identify poor decision learners and guide targeted remediation. Advances in the computational approach to learning whereby an agent tries to minimize risk when interacting with a complex, uncertain environment can offer insight to human learning systems.

Emulation of a Flying Boom Operator: The Dynamic Effects

Hung Tran

22116

Last year's paper "An Emulation of a Flying Boom Operator Using a Rule-Based Expert System" (I/ITSEC 2021) presented an approach to enhance the realism of the flying boom movement of a constructive tanker during a Virtual Air Refueling (VAR) training. The main contribution of that study is to document the actions that a boom operator performs to control the flying boom attitude and extension prior to, during, and upon disconnect. Additionally, the actions of a boom operator were subsequently used to derive a rule-based expert algorithm and implement it into a simulation of a KC-135 constructive tanker.

Because the boom motion and orientation are known to change the trim of the tanker aircraft during contact, further enhancement to the boom simulation will be necessary to reproduce the dynamic interaction of the receiver aircraft, the refueling boom, and the tanker aircraft. For instance, the tanker wake and atmospheric turbulence can disturb the motion of the flying boom; therefore, additional controls of the flying boom attitude will be required to enhance the emulation of the boom operator. Another factor related to the boom movement is when the boom extends, the inertia property of the flying boom will change as well. Therefore, this factor will also affect the movement of the flying boom as the aerodynamic force and moment change.

This present paper reviews and models these dynamic effects on the boom operator actions. The emulation of the boom operator presented in last year's paper was updated accordingly. The preliminary simulation results of this study demonstrated an enhancement of the realism of the flying boom movement, both visually and operationally, and consequently improved the simulation fidelity normally required for a Virtual Air Refueling training. We will present the simulation results of the implementation and discuss the crucial lessons learned from this effort.

Data-Driven Behavioral Modelling of an Air Defence System

Annemarie Burger, Maarten Schadd, Nico de Reus

22138

This research aims at learning the behavior of operators or role players in military simulators based on observed behavior. The paper describes the principle of so-called imitation learning that we used to learn behavior based on observations of players. We present an overview of the existing examples of the current application of data-driven behavior modeling in the military domain. We apply imitation learning to the army ground based air defense system (AGBADS) operator behavior, for which real-life data (from training events) was available. The data that is used in the learning process originates from the 2021 air-defense exercise Joint Project Optic Windmill (JPOW). After extensive pre-processing, multiple behavior models were constructed that can be used to provide fire control solutions (when to fire, the salvo size and which launcher to use) for a ground based air defense system given a tactical situation.

We create explainable models using decision trees, which can help during the after action review process to give trainees insight in their actions when training as an AGBADS operator. Using less explainable but more precise models, we can create replicas of behavior of an AGBADS, which can be used to simulate the AGBADS in training. Furthermore, the models could be used to aid decision support for AGBADS operators. We achieved quite reasonable performances with regards to the models, especially considering that we had to work with a discrepancy between logged data and the perceived situation as experienced by the operator, making it hard to create an accurate feature representation of the situation.

Virtual Advancement of Learning for Operational Readiness: Implementation and Transition of a VR Medical Simulation Capability for TCCC Responders

Karthik Sarma, Michael Barrie, John Dorsch, Talia Weiss, Jason Ribeira, Jennifer Polson, Srihari Namperumal, Ryan Ribeira

22142

High-fidelity medical simulation training is one of the few evidence-based interventions demonstrated to reduce medical errors and improve trainee readiness for medical techniques, tactics, and procedures. However, limitations of traditional Manikin-based simulation limit immersive simulation capabilities for the prehospital setting, as Manikins are also strictly limited in their capability to represent actual casualties and the psychoenvironmental characteristics of battlefield environments. In this paper, we report our adaptation of a commercially available civilian virtual reality (VR) medical simulation training platform for use in a novel curriculum for medical sustainment training of USAF Pararescuemen and other special forces personnel.

First, an interprofessional framework for virtual reality scenario concept development, specification, and engineering documentation is outlined, providing a roadmap for agile, interactive development of effective simulation training curricula. Second, a conceptual and practical framework for the specification of fully immersive deployed medicine simulation scenarios is described, including states, triggers, transitions, animations, medical assets, and other requisite information, with a model for integrating applicable tactics, techniques, and protocols from JTS Clinical Practice Guidelines and other knowledge sources.

Finally, the results of research effort will be described in detail, including detail about the 26 implemented scenarios (ACS, airway burn, anaphylaxis, asthma exacerbation, blast injury, blunt trauma, concussion, crush injury, cutaneous abscess, dive/gas embolism, extrication, lateral canthotomy, heat stroke, helicopter transport, HAPE, lumbar strain, mass casualty, meningitis, military working dog, pediatric abdominal pain, penetrating trauma, gas exposure, prolonged field care, seizure, TBI, and ventilator training), approaches to achieving full immersiveness in the virtual setting, environmental and battlefield realism modifiers and distractors, enemy action and non-player characters, and implemented interventions and procedures appropriate to the TCCC Tier 4 skillset. The results of initial testing and evaluation will be described, and a review of current ongoing continued research and evaluation efforts of the project will be provided.

Augmented Reality for Marine Fire Support Team Training

Colin Sullivan, Parker Fisher, Richard Schaffer, Sean Cullen, Supun Samarasekera, Kevin Kaighn, Taragay Oskiper, Rakesh Kumar

22164

Marine Fire Support Teams (FiSTs) consist of four or five Marines who direct aircraft, artillery, mortar, and naval fire in support of friendly troops on the ground. Traditional FiST training has been hindered by high costs and a limited availability of range time and associated supporting arms. Because of this, practicing together in the field is rare. To address this issue and provide FiSTs with the "sets and reps" required to develop and maintain proficiency, the Office of Naval Research 3D Warfighter Augmented Reality (3D WAR) program is developing an affordable augmented reality (AR) field simulator. AR is a technology that inserts computer-generated virtual objects in the user's real-world environment. The 3D WAR Marine Augmented Reality Team Trainer (MARTT) system allows for FiSTs in a field exercise to train with virtual entities and battlefield effects in their actual environment. Users wear an occlusive head-mounted display (HMD) which allows them to see virtual objects inserted over a camera feed of the real-world. Each FiST member wearing a MARTT system can see the same virtual scene from their own perspective, allowing for true team training.

Since 2019, MARTT demonstration and feedback events have been conducted at schoolhouses and training events throughout the Marine Corps. More recently, as the technology has matured, more in-depth assessments

and studies have been conducted on the technology's effectiveness. In this paper, we present the results of multiple evaluations of MARTT systems in training Marine FiSTs. Data collected includes assessments on the system's usability, immersion, and overall training utility. In particular, the paper will focus on the results from a three-month assessment of the technology by the Marine Detachment at the Fort Sill Field Artillery School.

A Vision for the Future of Military Medical Simulation

Matthew Hackett, Ph.D., Beth Pettitt, Ph.D., Jack Norfleet, Ph.D., Paul Kwon, Sterling Brodniak

22182

The military has been a pioneer in healthcare simulation for decades, rapidly integrating new training technologies into programs of instruction and pushing the utilization of simulation technologies for first responders and beyond. At present, the military training enterprise, in particular that of the Army, are at an historic inflection point, as the Synthetic Training Environment (STE) develops, holding the promise of improving and modernizing the next-generation of collective training. Concurrently, key enabling technologies, such as mixed reality, 3D printing, and artificial intelligence, are seeing explosive growth and development across the commercial and defense sectors. In order to lay the foundation for the next generation of medical training, the military medical community must leverage these ongoing efforts, while also undertaking critical science and technology (S&T) initiatives specific to the medical training use case. Within this paper, representatives from the Office of the Surgeon General, the acquisition community, and the S&T community have envisioned the future of military medical simulation, including a medical STE and the next generation of standalone medical training capabilities. This paper will present a research and development strategy, focusing on the technologies needed to actualize this vision, as well as a data strategy underpinning the technical implementation. To provide context, a series of use cases will be discussed illustrating how the implementation and execution of these strategies can result in improved training capability. Finally, the paper will conclude a comprehensive concept for the evolution of military medical training and actionable steps to achieve this goal.

Quantitative Analysis of Virtual-Reality Device Effectiveness for Cockpit Procedures Training

Mark Budgeon, Brandon Wolf, Margaret Merkle, Donna Senft

22195

Recent advances in computers and technology have made VR (Virtual Reality) devices with imbedded training applications focused on learning more commercially available. Additionally, there is potential to realize effective training with minimal human-instructor interaction. The authors were interested in whether a VR training-environment, coupled with software designed to effectively guide the student through a task, could improve the performance of a USAF pilot with minimal human-instructor guidance. The authors chose checklist execution as the measured task within static flight environments (e.g. the aircraft may be "airborne" but the focus is on checklist execution rather than aircraft movement/flight-path), and investigated whether training provided by the VR-device improved pilots' performance. Twelve subjects (n=12) were randomly selected, six had no VR training (nVR) and six had VR training (yVR). The six nVR subjects had completed a 3-month training program consisting of lectures, computer-based training, testing, and 20 hours of guided practice sessions at a physical cockpit station (aka "cardboard trainer"). Whereas, the six yVR subjects were only subjected to 20 hours of training within the VR device – they had no other academics. At the completion of training, both the nVR and yVRgroups were asked to complete the Before Starting Engines Checklist in a new environment – a full-motion simulator representative of the actual aircraft. Measures of "time to completion" (time) and "number of errors" (numerr) were used as indicators of student performance. The results showed that there was no statistically significant difference in time between the nVR and yVR subjects (p=0.8713); however, the mistake made by the yVR subjects was significantly less than the nVR subjects (p=0.0402). The author's conclude that a VR device, when coupled with software designed to focus the subject's training to the task, is likely responsible for the reduction in errors when compared with the older, established training technique.

Pilot Training Transformation: Early Results and Lessons Learned

Samantha Emerson, Kent Halverson, Cait Rizzardo, Ramisha Knight, Julia Brown, Audrey Reinert, Mark Hoelscher, Tracy Schmidt, Lisa Tripp, David Mills

22231

In the wake of the pilot shortage, the US Air Force (USAF) launched the Pilot Training Transformation (PTT) initiative—an ongoing exploration of new methods and technology applications in the Undergraduate Pilot Training curricula that proposes to decrease training time by over half (Lewis, Thompson, & Smith, 2019). A key aspect of the approach includes more frequent use of low-cost simulators; however, with flight-time being one of the strongest predictors of student pilot training outcomes (Trent & Aguilar, 2020), it is vital to ensure that the trade off between live and simulated flight results in pilots of at least equal—if not higher—quality than the legacy curricula. This paper contrasts the performance of graduates of the legacy curricula versus the revised PTT curricula across three training platforms: T-6, T-1, and T-38. Over 200 students were assigned to either the legacy or PTT curricula and after completing their respective curriculum, each flew a flight profile in a flight simulator. A specialized rating form, different from the standard training evaluation form, was developed to assess proficiency across a variety of skills to be demonstrated during mission planning, mission execution, and post-flight debrief. A cadre of Instructor Pilots were systematically trained to use the rating form to assess skills including basic aircraft control, task management, and overall proficiency. Preliminary analyses of the T-6 data suggest that student performance in the revised PTT curricula was significantly better than the performance of students enrolled in the legacy curricula across most outcomes while analyses of the T-1 data primarily show no significant differences between the students in the legacy and revised curricula. Full analyses across all platforms will be discussed. Lessons learned and best practices from this project will inform the development of future curricula and advance the training of the next generation of USAF pilots.

Using Digital Twins in Maintenance Operations and Training

Deepak Haste, Jeffrey Beaubien, Ph.D., Sudipto Ghoshal, Valarie Yerdon, Maartje Hidalgo, Jason Wong

22239

Maintenance Operations and Training is an integral part of equipment-lifecycle-management. The DoD has been using interactive-electronic-technical-manuals (IETMs) for troubleshooting and training purposes since the 1980s. However, IETMs are poorly suited to the complexities of modern equipment. Moreover, every time equipment is upgraded, IETMs must also be upgraded to reflect these changes. By comparison, model-based intelligent-reasoners (i.e., digital-twins) go a step further than IETMs by using a model as the "single-source-of-truth." With updated underlying models, the training content and troubleshooting capabilities remain relevant. Coupled with COTS head-mounted Augmented Reality (AR) devices, model-based intelligent-reasoners can support hands-free, Just-In-Time (JIT) training and troubleshooting support. Previous research suggests that such tools can help novices perform like experts by reducing the number of troubleshooting steps by half (Schlueter, 2018). Along with lowering the amount of time-in-training, the cost-savings have been found to be 20% of their hardware counterparts to build and update (Orlinski & String, 1981).

In this paper, we present a model-driven, agile DevOps-like "TrainOps" process that leverages digital-twins, COTS AR technologies, and learning-sciences concepts. When used in the maintenance environment as a JIT troubleshooting tool, the system can collect data about the most common errors made by the students and areas of concern during training. This information can then be channeled into the classroom environment to ensure that formal training events are grounded in operational reality and are learner-centric, focusing on the individual class. In this paper, we provide an overview of how digital-twins can be used to quickly and efficiently model downstream technical faults for use in maintenance training and operations. We also describe an automated process that captures standardized learning records to yield quantifiable metrics of learner performance, providing on-time feedback for both the instructor and the learner. Finally, we conclude with a series of best practices when adapting model-based decision-support tools for classroom-based training purposes through the use of scaffolding (Wood et al.,1976) and progressive hints (Shute, 2008).

Development of a Searchable, Web-Based Repository for Sharing AR/VR Training Assets

Jeffrey Beaubien, Ph.D., Wink Bennett, Ph.D., Richard B. Ayers, Rick Keithley, Kevin Audrain, James Belanich, Ph.D.

22252

Over the past decade, there has been an explosion of interest in the use of COTS Augmented (AR) and Virtual Reality (VR) technologies in training (cf. Clark et al., 2016; Zendejas et al., 2013). These technologies allow learners to interact with the environment using naturalistic gestures, thereby allowing them to focus on the training content rather than on the user interface. Similarly, they allow instructional designers to embed critical resources – such as task checklists – within the training environment to enhance the learning experience. Unfortunately, the development of ARVR training involves significant resource investment. For example, training developers first need access to realistic 3D models of the technology with which the learners must interact. If these models do not already exist, they must generate them with the aid of reference photos, videos, or Computer-Aided Design (CAD) files (USAF Scientific Advisory Board, 2019). Asset repositories are standard practice across numerous domains, including game development (GrabCraft) and 3D printing (Thingiverse). Bringing this capability to the USAF will align it with the rest of the ARVR industry and will minimize the need to "reinvent the wheel" on every new training application. In this paper, we describe the Air Force Research Laboratory's multi-year effort to design and develop a secure, web-based Community of Practice (COP) that will allow USAF instructional designers to quickly and easily share 3D models, reference photos and videos, and CAD models, among others. In addition to the asset repository, the system will help users to learn from one another via discussion groups, monthly webinars, and community-developed knowledge products. This paper will describe the results of our needs assessment process, our high-level system design principles, screen captures of the actual software, user feedback data from our evolving system designs, and lessons learned regarding the development of online COPs.

Blending AR and VR to Increase Situational Awareness during Training

Austin Garcia, Eliot Winer, Ph.D.

22280

Virtual training is estimated to make up $14 billion of the US military budget annually, with most going towards virtual reality (VR) and augmented reality (AR) applications. Advancements in commodity VR and AR head mounted displays (HMDs) have driven much of this recent growth by making virtual training solutions more practical and cost-effective. However, these training applications create a disparity in virtual environment perception between a trainer and a trainee. A trainee is in the HMD while a trainer is usually not, creating a barrier for collaborative communication. One solution is to display a trainee's viewpoint on a 2D display, but this makes it difficult for a trainer to have adequate situational awareness of a trainee. Another option is to place a trainer inside the virtual environment. This offers improved perception of a trainee's progress but removes a trainer's real-world situational awareness, which can be vital when facilitating training on complex processes or equipment. Neither of these options provide an adequate solution to bridge this visual communication gap.

User studies have shown that asymmetric collaboration between VR and AR users results in improved performance and engagement during collaborative tasks. These findings show the potential of applying asymmetric collaboration for commercial and military VR training. This paper introduces a prototype AR mobile application that establishes a new method for asymmetric collaboration within a training scenario. The approach uses body tracking to identify a trainee and align the VR scene around them in real-time. Using AR, a trainer can view a trainee in the real-world with augmented content around them replicating the virtual environment. Occlusion of the trainee's body accurately portrays their depth within the scene. Evaluation of this application found that the implementation of real-time body tracking and networking on a mobile device can maintain an operable framerate.

Transforming Team Training: The Influence of Virtual Environment Features

Beata-Noemi Balint, Helen Dudfield, Brett Stevens

22285

To enhance operational capability, military teams must possess both teamwork and taskwork knowledge, skills, and attitudes. With the growing availability and maturity of consumer-ready Head Mounted Displays (HMDs), there is an increased interest in adopting immersive Virtual Reality (VR) systems for team training. Whilst desktop-based Virtual Environments (VEs) are evidenced as effective delivery methods for team training (e.g. Barton, Bruce, & Schreiber, 2017), evidence of a training benefit for emerging immersive technologies over desktop systems is inconclusive (Balint, 2021). To optimise future team training systems, it is important to develop an understanding of features endogenous to VEs that may positively affect team training and competency assessment. Building on an exploratory study (Balint, Stevens, Dudfield and Powell, 2020), this paper presents an empirical study that examined the effect of three features, immersion, presence, and psychological fidelity, on the ability of individuals to engage in teamwork. The study design was quasi-experimental between-subjects conducted remotely using an online game (PayDay 2). Seventy-seven experienced gamers were divided into 20 ad hoc teams and were asked to play a cooperative PayDay 2 scenario on a desktop (14 teams) or an HMD (6 teams). Data analysis indicated that VE features examined did significantly predict perceived teamwork, over and above previous suggested confounds, such as usability and prior experience with the task and interface. However, not all factors had equal influence. Once usability of the system is perceived to be high enough, so as not to distract users from their task, presence appears to have the most influence on quality of teamwork. Thus, VE features need to be considered when designing systems due to their moderating effects on the ability of individuals to engage in teamwork. Furthermore, the results suggest that designers of future military VE team training systems should focus on maximising presence to support teamwork.

Cloud Full of Predators: Virtualizing RPAs for Constructed Training Exercises

Lillian Campbell-Wynn, Ph.D., Margaret Merkle

22297

For Air Force Special Operations Command (AFSOC), the availability of Remotely Piloted Aircraft (RPA) virtual simulation capabilities to augment Special Operations Forces (SOF) training is of primary interest. AFSOC relies on the Air Force Synthetic Environment for Reconnaissance and Surveillance (AFSERS), the DoD flight simulation/training system for many RPAs, airborne platforms, and applications. In the ever-expanding demand for realistic training, moving this RPA simulation to cloud based architecture is significant – having the ability to spin up and down, capacity to meet mission needs in a cost effective manner.

The Air Force teamed with the Army's Joint System Integration Lab and Trek10 to address Operational Training and Test Infrastructure shortfalls with an extensible cloud based infrastructure through a Small Business Innovation Research (SBIR) initiative. The project objectives included cloud-enabling AFSERS components; providing appropriate access; and addressing cybersecurity credentials to support Joint Terminal Attack Controller and Combat Air Operations Center training.

Trek10 provisions AFSERS components as a service so end users can self-configure based on training needs through decoupled state storage and dynamic, automated computing provisioning. Critical data needs, mission configuration parameters, and terrain files for simulations analytics persist sufficiently in a secure cloud repository. There is automatic dynamic cloud resources launching, tailored and on-demand graphics, and processing requirements execution. Files load through secured streaming connections for end users, federation participants, and cloud resources.

The team built an initial capability to validate cost, technical execution and determine a path to long-term adoption. The investigation included interoperability with key simulation environments, DoD Cloud Hosting environments, networking requirements, and a roadmap to SIPRNET utilization. The findings revealed cloud-based infrastructure will standardize

components; reduce IT footprint and subject matter expertise, and increase accessibility and scalability, thereby providing substantial cost avoidance with improved warfighter training and readiness.

Identifying Unique Physiological Indicators of Virtual Reality Sickness

Olivia Fox Cotton, Kevin Durkee, Justin Morgan, Sarah Meyer, Sheila Galbreath, Brennan Cox, Ph.D., Gabriella Severe-Valsaint, Ada Mishler, LCDR Michael Natali, Ph.D., USN, Leanne Hirshfield, G S Rajshekar Reddy, Cara Spencer, Gavin Zimmerman

22308

Navy pilots rely heavily on simulator technologies to train and develop critical skills. It is important to evaluate the impact of new training technologies as they emerge. While virtual reality (VR) is a promising tool for immersive training, VR sickness is common, leading to a range of disorientation, oculomotor, and nausea symptoms (Kennedy et al., 1993). The goal of this paper is to assess the feasibility of deriving physiological signatures of VR sickness. Identification of physiological signatures specific to VR exposure provides the foundation for both future predictive models of VR sickness and potential augmentation strategies to prevent or ameliorate the symptoms of VR sickness, increasing the utility of VR as an immersive training tool. While prior research has demonstrated physiological changes during VR exposure (Martin et al., 2020), we will also consider the impacts of workload variations and individual differences. To do so, a study is underway using a setup modeled after the U.S. Navy's VR flight training environment in which participants perform various flight maneuvers that may induce VR sickness (e.g., barrel rolls and 180° turns). This study investigates whether VR training induces detectable changes in human physiology, and if so, what relationships exist between physiological measures and the previously validated Virtual Reality Sickness Questionnaire (VRSQ). Further, the Motion Sickness Susceptibility Questionnaire (MSSQ) is employed to assess individual differences in susceptibility as a potential moderator of VR sickness and the NASA Task Load Index (NASA-TLX) is administered to control for any changes in workload across trials that may also induce physiological changes. This methodology allows us to better understand what degree of physiological change is unique to VR sickness. We hypothesize that heart rate, respiration, and blink rate will show strong associations with VR sickness. Data collection efforts are ongoing but will conclude prior to paper submission.

DoD Learning Enclave: Realizing the Defense-wide Learning Ecosystem

Brent Smith, Sae Schatz, Ph.D.

22313

This paper summarizes the history, purpose, and progress in implementing a Defense-wide learning ecosystem—parts of which reached an Initial Operational Capability this year. A "learning ecosystem" is a system of systems comprised of various end-user training/education technologies and enterprise software services connected via a data-centric modular open systems architecture.

For nearly a decade, DoD's Advanced Distributed Learning (ADL) Initiative has been developing the data standards and business rules for a learning ecosystem, called the "Total Learning Architecture" (TLA), and since 2018, the ADL Initiative has led the Pentagon-directed Enterprise Digital Learning Modernization (EDLM) reform designed to turn this vision into a reality. At prior I/ITSEC conferences, we've published status updates about the TLA, EDLM, and components of the DoD learning ecosystem. This paper marks a notable milestone. It comprehensively describes the technology components—no longer as concepts or early prototypes but as functional capabilities transitioning into operational use.

The paper begins with a background review of the rationale, formal direction, and anticipated benefits. Next, it delves into the specifics of achieving the learning ecosystem, including the TLA data backbone and newly implemented DoD Learning Enclave (DLE). The DLE is a cloud-based set of enterprise digital learning systems, conformant learning activities, and data management infrastructure. It's currently hosted on an Air Force cloud environment at Impact Level 4 and includes 11 components, such as an enterprise course catalog, TLA data backend, and commodity learning delivery technologies, such as a learning management system. These systems are available for all DoD Components, and DoD organizations and vendors are expected to, at least, implement the data and interface standards required to be interoperable with the centralized systems. The paper closes with technical guidance for DoD organizations and industry partners on meeting these requirements—so we can collectively accelerate the DoD's training (and education) transformation.

Don't Judge a Book by Its CoVR: Learning and Training in Virtual Reality; The Effects of Two Levels of Immersion

Kendall Carmody, Meredith Carroll, Ph.D.

22324

Immersive devices, such as virtual reality (VR) devices are swiftly being integrated into military and civil operations as advanced tools for training, with studies observing the beneficial aspects of employing these devices for training cognitive skills (Xie et al., 2021). However, further research is needed to understand specific characteristics of the learning effectiveness of the technology, and to identify which levels of immersion benefit specific learning constructs in training. This study examined the effect of immersion on four constructs related to learning, including memory retention, learner engagement, learning performance in the form of knowledge acquisition, and perceived learning in a virtual maintenance training task. The study aimed to determine how these constructs are impacted by two different levels of immersion during a virtual maintenance training task by means of either (a) a desktop computer and keyboard; Low-immersion Virtual Reality (LiVR) or (b) a virtual reality headset and controllers; High-immersion Virtual Reality (HiVR). To achieve this, a between-subjects experimental design was employed with 25 participants completing a maintenance training task on a simulator developed in collaboration with the Air Force Research Lab's (AFRLs) Gaming Research Integration for Learning Laboratory (GRILL). A memory retention quiz, the User Engagement Scale (UES) short-form, A pre-post knowledge assessment, and the Cognitive, Affective and Psychomotor (CAP) Perceived Learning Scale were administered to capture the dependent variable learning constructs, with level of immersion acting as the independent variable. Results revealed that both immersive testbeds enhanced participants' knowledge acquisition and that engagement was significantly higher in the HiVR condition. Trends were also observed with respect to the impact that immersion had on participant's memory retention. The findings can help to inform the procedural training community on the benefits of immersive devices with respect to virtual environment training for hands-on spatial tasks.

What's My Status? – Best Practices for Self-Led Debriefs

Elaine Choy, Emily Anania, Ph.D., Beth Atkinson, Ryan Wohleber, Ph.D., Brian Stensrud, Ph.D., Kay Michel, Ph.D.

22379

Debriefs – a tool critical for effective training – are traditionally facilitated, meaning they are led by an individual (e.g., instructor, teammate). While there are various ways to execute facilitated debriefs, the combination of expert guidance and structured discussion has proven particularly fruitful in military domains (Keiser & Arthur, 2020). However, with increased use of asynchronous or remote learning, and automated or instructor less training systems, it is essential to consider approaches to maximize training effectiveness through automated debriefing capabilities when immediate facilitated feedback is not available (Importance to community). As a first step to defining self-led and non-traditionally facilitated debrief capabilities, we review best practices for facilitated debriefs. This supports identification of gaps in effectiveness that may exist due to the nature of non-facilitated debriefs. Further, adapting those best practices to non-guided debriefs serves two purposes: to provide a starting point to researching which changes are effective in this environment, and to document a structured approach to developing non-facilitated debriefs that are more familiar to the user. To illustrate non-facilitated debriefing concepts derived from this analysis, we will employ an emerging game-based communication trainer for H-60R crew members as a use case. This training system simulates realistic job task performance related to communication behaviors. This paper will focus on potential ways to increase training effectiveness during a self-led debrief. For example, multiple debrief methodologies and structures (e.g., mission, thematic, timeline) will be explored. Further, we will review ideas derived from traditional debriefs such as leveraging self-report performance data for comparison with automated metrics to emulate a feedback discussion. The objective of this analyses and requirements development is to inform design

of a testbed for laboratory evaluation of concepts hypothesized to provide effective instructor less debriefs. As a result of these activities, the authors aim to define best practices for self-led debriefs.

Directed Self-Regulated Learning via Learning System Support

Jennifer Fowlkes-Ratliff

22412

Potentially, one of the strongest military assets in today's complex warfare domains are personnel who are self-starters in terms of being able to quickly adapt to new missions, technologies, and other job challenges; in other words, personnel who are self-regulated learners. Self-regulated learning (SRL) allows individuals to select learning topics based on job demands or other interests and manage their learning through processes such as goal setting, strategy selection, and monitoring. Decades of research show that the behaviors associated with SRL are linked to positive learning outcomes. However, despite the benefits of SRL, it is also well-recognized that learners do not automatically use strategies that support SRL or use them effectively. Given the state of the research and the importance of SRL, the purpose of this paper is to describe a competency framework for self-regulated learning that was developed to support experimentation with Army University. This framework was tailored for adult learners who, because of factors such as work demands, schedule variability, and proficiency levels, have difficulty learning how to learn.

This paper delineates how different learning systems can be used to provide SRL guidance and assessment based on data generated by conforming to the Advanced Distributed Learning Initiative's Total Learning Architecture (TLA). The TLA is a collection of data interoperability standards and business rules that enable data-driven, comprehensive, and responsive life-long learning opportunities. This paper will delineate how the TLA data can be used to support "directed" SRL (Brydges, Dubrowski, & Regehr, 2010), in which learners are taught, mentored, monitored and assessed as they engage in SRL.

Reference cited: Brydges, R., Dubrowski, A., & Regehr, G. (2010). A new concept of unsupervised learning: directed self-guided learning in the health professions. Academic Medicine, 85, S49-S55.

Training Alchemy – Effectively Converting Traditional Training Content to Gold

Cait Rizzardo, Summer Rebensky, Ph.D., Brian Flowers, Jonathan Reynolds, Peter Neubauer, Kent Halverson

22427

Many institutions are looking to pivot their educational content and training methods to virtual reality (VR). A review of VR training research has demonstrated the ability to improve psychomotor skills, spatial tasks, and knowledge acquisition (Abich et al., 2021). However, training programs transitioned to VR can result in little to no learning gains compared to traditional methods—or in some cases worse outcomes as a result of VR technology design that does not align with or satisfy the task requirements (Howard et al., 2021). Furthermore, although research has demonstrated benefits in novice training environments, less has been done to determine if these methods can lead to mastery of the learning objectives (Fletcher et al., 2017). A focus on learning objectives and the learning strategies within VR will be key to ensuring the highest potential learning gains (Abich et al., 2021). The purpose of this paper is to describe a repeatable process that effectively links LOs to the most appropriate learning technology or environment (which may not be VR), aligns training needs with technological capabilities, and assists with decision making under budget constraints. An example use case of a process to transition traditional content into VR will be discussed. Establishing a standard, repeatable process is critical in ensuring that modern training resources are effectively leveraged to still achieve necessary training outcomes. The paper will provide guidance for considerations in implementing VR training and best practices for identifying when to use VR for training and education.

Game Jams – A New Form of Rapid Prototyping

Mike Bianchini, Chad Hoover, Austin Pinzon

22434

Military training software development traditionally used slow-moving approaches such as the waterfall model, but in more modern times, rapid prototyping methodologies such as Agile have emerged as an effective way to achieve working solutions quickly. Military training and gaming are closely connected, and an additional form of rapid prototyping from the game development industry is being explored for military software development. "Game jam" events started in 2002, where game developers meet for a short, intense time frame – usually 48 hours - and make a game based on a theme. In November 2021, a game jam was presented by the Orlando game developer organization, Indienomicon, that focused specifically on prototyping military training solutions for cybersecurity, PTSD, and other challenges. This paper will explore the idea of using the game jam process for rapid prototyping of military training solutions to accelerate the initial concept and design phase.

A major benefit of a game jam is a tangible, playable product in a short amount of time. Within a matter of days, teams collaborate and focus on a specific need and produce a functional piece of software to be evaluated. If multiple teams are given the same challenge, they will produce different solutions, providing multiple perspectives/options for the customer. Additionally, game jams have shown to teach not just "hard" skills such as planning and debugging, but "soft" skills such as communication, teamwork, and respect. This paper will outline several game jam successes, where games were later developed into full-fledged commercial products. It will describe pros and cons and use cases where the game jam process will be valuable. Finally, it will explore the Agile methodology, how it relates or compares to game jams, and how game jams can be used in conjunction to accelerate change in the military training software development industry.

Operational Assessment of a CV-22 Virtual Maintenance Training Solution

Beth Hartzler, Wink Bennett, Ph.D.

22437

The CV-22 Osprey fills an important need for increasing the United States Air Force's (USAF) reach into remote and contested environments, but its unique design and capability profile leads to substantial operation and maintenance costs. Moreover, such a complex platform requires highly-skilled specialists to ensure optimal support of operational tempo, but limited fleet size translates to significantly constrained resources for training maintainers. Maintainers' opportunities for hands-on training is further complicated by varying aircraft availability, task demands, and operational tempo. To supplement traditional training opportunities, Link developed the Immersive Maintenance Guide (IMG) as an adjunct training tool that promotes knowledge and skill development among new maintainers. The IMG allows 3-Level maintainers to virtually and independently "walk" through the steps involved in a broad selection of maintenance tasks. A collaboration between the Rapid Sustainment Office (RSO) and the Air Force Research Lab (AFRL) evaluated the IMG using both objective and subjective measures to quantify the holistic benefits of the system over a five-month evaluation period in comparison to maintainers who used only the traditional training resources. A comparison of the two groups revealed substantial improvements for both Experimental and Control participants, though advances over baseline were highest among those who used the IMG. This was evident for participants' knowledge of the task steps, such that Experimental participants' demonstrated a 42% greater improvement over their peers, and for their self-efficacy to lead completion of the task. Moreover, these gains were significant for simple and routine tasks as well as those less commonly encountered. As a demonstration of training benefits, the current assessment revealed the IMG's promise as a valuable tool for improved task knowledge and an increased sense of readiness for task completion, gains which in turn likely contribute to increased combat power.

Multimedia and Immersive Training Materials Influence Impressions of Learning but Not Learning Outcomes

Benjamin Clegg, Alex Karduna, Ethan Holen, Jason Garcia, Matthew Rhodes, Francisco Ortega

22459

Although the use of technologies like multimedia and virtual reality (VR) in training offer the promise of improved learning, these richer and potentially more engaging materials do not consistently produce superior learning outcomes. Default approaches to such training may inadvertently echo concepts like naïve realism in display design, and desirable difficulties in the science of learning - fostering an impression of greater learning dissociated from actual gains in memory.

This research examined the influence of format of instructions in learning to assemble items from components. Participants in two experiments were trained on the steps to assemble a series of bars, that resembled Meccano pieces, into eight different shapes. After training on pairs of shapes, participants rated the likelihood they would remember the shapes and then were administered a recognition test.

Experiment 1 instructions employed step-by-step diagram versus a video of the shapes being constructed in a VR environment. The results showed that materials from the video did not change learning outcomes compared to the standard, drawing-based instructions. However, the richer materials in the videos did increased confidence in learning.

Experiment 2 compared training viewed within the immersive VR system to the videos. No differences in learning or judgments of learning were found, but a cross-experiment comparison showed the metacognitive judgments were still elevated compared to the static diagrams. Even richer cues in the VR viewing condition did not further accentuate judgments of learning compared to the video. This highlights factors that may and may not influence our sense of learning.

Overall these findings illustrate how future workers might mistakenly come to believe that technologically advanced support is enhancing their learning, even if it does not, and how the design of instruction might be tempted by those same cues towards complex forms of training.

Individualized Training – The Missing Link of True Training Effectiveness & Capability Sustainment

Jenna Tuck

22460

We have already witnessed how the applications of technological advancements have provided increases in learning outcomes for all learner types. For example we have seen; higher levels of motivation and engagement through the adoption of immersive technologies; more readily available relevant data through advancements such as xAPI; greater, more rapidly available understanding of learner outcomes with applications of Artificial Intelligence (AI), and increased capabilities to rapidly gather, analyze, and process all of this data through increased computational capabilities. However, an understanding of overall learner outcomes is just the beginning—technology will continue to become an increasingly integrated part of our lives, and with it, a previously unimaginable quantity of individualized data available at the point of need.

With this individualized data, we need to look not only to track learner outcomes—but track, analyze, and understand how effective different pedagogical approaches of learning are, at the individual level. In this presentation we will discuss; the critical relationship of individual preferences on near/far transference and training effectiveness; the role that advancements in cloud computing will play in increased data delivery when/where it is most valuable; and how 'Big Data' and AI will enable training to be delivered to learners in a way that maximizes its effectiveness for that learner. Further, we will discuss how the focus on training outcomes at the individual level correlates to overall training effectiveness between echelons—paving the way for adaptations in training that by design results in training that can be completed faster, by more individuals, with better outcomes – and ultimately provide sustainability of workforce capabilities in light of uncertainties.

TUTORIALS

BEST TUTORIAL

Practical Guide to Learning Engineering

Sae Schatz, Ph.D., Jim Goodell

22T15

Alexander Fleming discovered penicillin. However, the Nobel Prize–winning scientist and his colleagues never developed the ability to produce the drug at scale. By June 1942, US labs had only enough penicillin available to treat about ten patients. The urgency of lives being lost in the war meant that production of penicillin needed to move out of the laboratory and into mass-production. This was no longer just a scientific endeavor; it required engineering. The goals of science and engineering are different. The goal of science is to discover the truth about the world as it is. The goal of engineering is to create scalable solutions to problems using science as one tool in that endeavor.

Learning engineering is a process and practice that applies the learning sciences, using human-centered engineering design methodologies and data-informed decision-making, to support learners and their development. Learning engineering brings together professionals from different fields, including the learning sciences, assessment, learning experience design, software engineering, and data science.

Learning engineers design learning experiences, but that's not all they do. They also address the contexts and conditions that lead to great learning. These might include the architecture of physical or virtual learning environments, social structures, and learners' mindsets as well as more obvious targets such as curriculum design, educational technology, and learning analytics.

This tutorial introduces learning engineering, starting with its definition, purpose, and foundations. Next it covers the core components, beginning with the learning engineering process model and followed by the field's primary contributing disciplines: learning sciences, human-centered design, engineering, data collection, data analytics, and ethical design. This initial portion of this tutorial will give attendees a solid understanding of the discipline as well as its definitions, utility, and distinctions from related fields. We will use real-world case studies throughout to illustrate concepts.

Following this, we will outline the steps practitioners can use to form learning engineering teams and to execute applied learning engineering processes. This portion will include tools and recommended practices for uncovering learning challenges, assembling and managing lean-agile learning engineering teams, creating human-centered designs, integrating learning science, motivating learning, implementing learning technology (particularly at scale), instrumenting learning for data, and using learning analytics to continuously improve outcomes.

This tutorial is a primer suitable for anyone involved—directly or indirectly—in training, education, or talent management. This tutorial will give attendees important tools to optimize their work.

BEST TUTORIAL

A Comprehensive Introduction to Medical Simulation

Roger Smith, Ph.D., Danielle Julian, Alyssa Tanaka, Ph.D.

22T30

Simulation tools and techniques have been a part of acquiring medical knowledge and skills for over 4,000 years, with more scientific approaches emerging hand-in-hand with the European Renaissance. These devices were initially used as a means to convey homeopathic experience and

the knowledge gained through cadaveric dissection. More recently, the devices have been computerized and restructured according to modern learning theories.

This tutorial is a comprehensive overview of medical simulation to include their history, learning taxonomies, devices and techniques for representing external and internal anatomy and physiology, the role of team training, specialized military medical applications, the growing role of AI in medical simulation, criteria for current simulation-based medical training accreditation, and their role in preparing for pandemics like COVID-19. The story includes manikins, part-task trainers, game-based systems, surgical simulators, standardized patients, physical prostheses, team training events, and certifications. These categories are drawn from taxonomies initiated by the American College of Surgeons and the Society for Simulation in Healthcare.

The innovation and acceleration section shares new tools, techniques, and technologies that are changing the nature of traditional training systems and events.

BEST TUTORIAL

Putting the When and Where into Simulations

S. K. "Sue" Numrich, Ph.D., CMSP

22T47

All simulations take place somewhere on terrain or in the sea or atmosphere, amidst natural and man-made structures. The action takes place at a particular time of day and season of the year. These descriptors of the when and where of a simulation are not simply visual effects, but in a constructive or virtual world they provide a real context for the behaviors of humans, vehicles, sensors, communications and weapons. This tutorial is intended to introduce the simulation user and developer to the fine art of creating the environmental playground for a simulation. The tutorial will cover the land, atmosphere and the ocean, citing sources for data and the problems that typically exist in the original source data as well as those that inevitably result from combining information from a variety of diverse sources. The difference between geo-specific and geo-typical will be discussed and why one is chosen over the other. The issues of correlation will be illustrated within a single domain (just land features), across different simulations, and across domains (correlating land, sea, and air). The tutorial illustrates how the environment and its changes affect simulated entities – vehicles and sensors in particular. Finally, the tutorial shows how a dynamic environment can be developed and provided to the simulation. As part of the discussion, the tutorial will direct attention to the DoD-provided sources for creating a reasonably correlated synthetic environment and the emerging international standards for representing environmental data. The effects of the environment span not only the domains of land, sea, and air, but electromagnetics, space and cyber by way of communications effects.

Simulation Conceptual Modeling Theory and Use Cases

Jack Borah

22T10

Simulation conceptual modeling is a critical step in simulation development frequently overlooked in the rush to demonstrate program progress. A simulation conceptual model is an abstraction from either the existing or a notional physical world that serves as a frame of reference for further simulation development by documenting simulation-independent views of important entities and their key actions and interactions. A simulation conceptual model describes what the simulation will represent, the assumptions limiting those representations, and other capabilities needed to satisfy the stakeholder's requirements. It bridges between these requirements and simulation design.

This tutorial will present the theory and application of simulation conceptual modeling as documented during the research done by the NATO MSG 058. In addition, Use Cases that have been drawn from previous conference presentations will be presented to illustrate how conceptual modeling has been performed. Additional work is necessary to mature the state-of-the-art of simulation conceptual modeling before a recommended practices guide could be standardized. This tutorial has been created to continue the maturation of the simulation conceptual modeling best practices.

The WHY & How of eXtended Reality (XR) Enterprise Adoption

Kay Stanney, Ph.D., Matt Archer

22T12

The business case for adoption of eXtended Reality (XR) technology within Industry 4.0 is compelling… increased productivity, training effectiveness, engagement, retention, and motivation, with decreased time to proficiency, human error, downtime, and operating costs. Yet, adoption has been languid, as barriers to XR implementation abound. While high-quality, affordable, wearable augmented reality (AR) and VR (virtual reality) gear are readily available, high-value use cases are little understood; start-up costs are high; the requisite supply of compelling content and anticipated high-end user experience are yet to be realized; there are a paucity of empirical studies on learning outcomes and performance gains; there are no readily available tools to support scalability and sustainability; and cybersickness is still a challenge. To facilitate adoption, XR ecosystems are needed that can readily overcome the current lack of content by automating the production process. At the same time, content must be coupled with XR enablers, including new XR-specific user experience design paradigms that are contextually rich, intuitive, and uniquely suited to 3D interaction, along with the ability to plug-in to digital twins that reflect the reality and complexity of real-world systems to fuel predictive analytics and close the loop between operator and system. The future of industry relies on the ability of such XR ecosystems and XR enablers to generate value-added use cases that not only justify adoption costs but proportionally outweigh them. This tutorial will dive into how enterprises could derive immense value from XR adoption by providing insights into: key drivers of XR adoption; key barriers to XR adoption; value-added uses cases; and guidelines on where an organization might consider starting their XR adoption journey.

TENA, Interoperability, and Data Management

Edward Powell, Ph.D.

22T13

The Test and Training Enabling Architecture (TENA) provides an advanced set of interoperability software, interfaces, and connectivity for use in joint distributed testing and training. This tutorial will discuss how TENA works and why it is important to the test and training communities, with some comparison to other interoperability architectures. TENA provides testers and trainers software such as the TENA Middleware—a high-performance, real-time, low-latency communication infrastructure that is used by training range instrumentation software and tools during execution of a range training event. The standard TENA Object Models provide data definitions for common range entities and thus enables semantic interoperability among training range applications. The TENA tools, utilities, adapters, and gateways assist in creating and managing an integration of range resources.

In constructive simulation environments, the amount of data collected in each event can be large. But in a live-virtual-constructive test or training event, when data from each individual live entity is collected in addition to range data, telemetry data, and simulation data, the amount of data collected can be astronomical. The estimate for data collected from a 16-ship F-35 formation versus 16-ship aggressor aircraft formation, embedded in a larger LVC scenario, is over 50 terabytes for a two-hour event, about half of which is video. Analyzing this data efficiently, not to mention providing immediate after-action reviews to the participants, requires a new mechanism. TRMC has developed a Knowledge Management/Big Data Analysis architecture and implementation seamlessly connected to both the TENA architecture and other range communication and storage mechanisms to tackle this problem.

The I/ITSEC Professional Development Primer: M&S Fundamentals, Certification, and Contemporary Applications

Kevin Hulme, Ph.D., CMSP

22T17

This Tutorial serves as a holistic primer for Professional Development across the full spectrum at I/ITSEC 2022, whose prevailing theme is to Accelerate Change by Transforming Training (ACTT)! Major topics include a notional introduction to core I/ITSEC fundamentals (e.g., M&S basics; the Live-Virtual-Constructive/LVC taxonomy; Model Verification/Validation), followed by an overview of the officially recognized (and recently upgraded) professional designation within the M&S discipline: the Certified Modeling and Simulation Professional (CMSP).

To tie it all together, the primary technological lynchpin for this Tutorial is an example-driven exploration of contemporary applications - culled from peer-reviewed literature - to visualize how core principles (e.g., M&S, LVC, VV&A) are being actively leveraged within diverse fields and disciplines: 1) Engineering Design/Manufacturing, 2) Sustainable Transportation, 3) Education, Training, and STEM, 4) Health Care (e.g., COVID-19), and finally, 5) the Entertainment Industry, for which the greater Orlando region is world-renowned.

Accreditation of Simulation-Based Experiments and Training: Beyond the M&S

Thomas Yanoschik, CMSP, Major Sean Fraser, USA, CMSP, Cynthia Dunn, CMSP, Major Larry Baca, USA, CMSP, Stephen Miller

22T18

The Department of the Army has no individual or organization that accredits a simulation-based experiment (SIMEXp). Army Regulations require that the modeling and simulation (M&S) be accredited – but not any of the other components required to execute a SIMEXp such as the operational scenario, analysis, or computational environment (hardware and network, for example). The purpose of this tutorial is to present a framework for overall SIMEXp or training event accreditation and enable attendees to understand all the areas which must be accredited for the overall accreditation of a SIMEXp. Accreditation of the M&S will be discussed, as it serves as the foundation for an overall accreditation, but there are other equally important components requiring separate accreditations. After participating in the tutorial, attendees will be able to identify the components of tactical and operational scenarios which must be validated by current warfighters – and that the person who accredits those aspects must have credible knowledge of the current state of doctrine, military organizations, and operational concepts (friendly and enemy) to be studied. Attendees will learn that a properly certified expert must accredit the physical and computational environment- that software, operating system, information assurance, and network updates or changes haven't impacted the performance of a previously accredited simulation. The same applies if the event is being executed in a distributed environment- what other locations have updated or changed in their environment may cause performance changes across the federation. The hardware and network on which they are running to ensure processors are robust enough to execute as required, the network transmission speeds are sufficient, and no packets are being lost during execution. Finally, attendees will learn how to design and assess the analytical methods used during a SIMEXp to ensure accreditation of the analytical portion of the SIMEXp. The analysis plan, data collection and reduction methodology, and computational methods for analyzing the data must all be documented and accredited in a peer-reviewed final report for the overall SIMEXp to be accredited. This tutorial is intended for those interested in gaining a better understanding of proper SIMEXp or training event design and why more than just the M&S must be accredited.

Introduction to HLA

Björn Möller, Katherine Morse, CMSP

22T21

The High-Level Architecture (HLA) is the leading international standard for simulation interoperability. It originated in the defense communities but is increasingly used in other domains. This tutorial gives an introduction to the HLA standard. It describes the requirements for interoperability, flexibility, composability and reuse and how HLA meets them. It also describes the new features of the most recent version: HLA Evolved (IEEE 1516-2010) and the upcoming HLA version (HLA 4). Finally, it provides some recent experiences of the use of HLA in NATO M&S groups as well as an overview of recent evolution of Federation Object Models for military platform simulation, space simulation, cyber simulation and air traffic control simulation. This tutorial is intended for all audiences; however, some familiarity with basic principles of distributed computing is recommended.

Introduction to Defense Modeling and Simulation

John Daly, James Coolahan, Ph.D.

22T22

This tutorial will describe the fundamental technologies, terms and concepts associated with Modeling and Simulation (M&S) as used in the U.S. Department of Defense (DoD). The tutorial will cover key M&S terms and concepts that describe M&S technology, development, and application. It will include: (a) M&S terminology and concepts; (b) M&S technology, architectures, and interoperability protocols; and (c) The processes for developing valid representations of: DoD warfighting capabilities, threat capabilities, complex systems, and mission environments. The attendee will become familiar with how M&S is used in the DoD for operational purposes - especially training and other areas of direct warfighter support. This tutorial will highlight the role of Verification, Validation and Accreditation (VV&A) in ensuring credible models and simulations meet the needs of their users, the use of M&S Standards, and the integration of M&S with DoD Mission Engineering and Digital Engineering in the development and acquisition of DoD warfighting capabilities. The tutorial will describe the characteristics and associated challenges of M&S application within DoD functional areas including Training, Analysis, Acquisition, Test and Evaluation, Planning, Medical, Mission Engineering, Autonomy, Artificial intelligence, DoD Research and Development/Employment, and Intelligence. The tutorial will also identify accessible DoD M&S information resources.

A Process for Distributed LVC Event Integration and Execution

Michael O'Connor, CMSP, , Kenneth LeSueur, Ph.D., Roy Zinser, Brett Boren

22T23

Integration and execution of large distributed Live, Virtual, Constructive (LVC) events consume substantial time and resources. While the underlying distributed LVC technologies are mature, the processes for integrating events are not. The IEEE Std 1730-2010 Distributed Simulation Engineering and Execution Process (DSEEP) standard defines a process model for developing an event. DSEEP defines a set of seven steps divided into activities. The process model provides representative inputs and outputs for each activity. However, the user still must instantiate the process and develop artifact templates. The development of a robust process based on DSEEP is a substantial effort.

The goal of the process is to produce a verified distributed LVC environment to conduct the event. While distributed LVC environments can be created without using a process, not using a process adds risks to the event. The first risk is that the integration fails, and it may be difficult to discover the reason. The second risk is that the unverified environment produces invalid results that might not be apparent until the results are used.

An instantiation of DSEEP was developed based on the authors' integration and execution of many distributed LVC events. This implementation has nine steps, divided into 27 activities. This process adds two additional steps to the process. One of the steps adds a tabletop wargaming step to work through the requirements. The second additional step develops a digital twin of the target system. A detailed set of processes, templates, and guidance on how to perform the selected activities is provided. The process covers the integration of simulations and tactical systems to meet the objectives of the LVC event.

The tutorial will provide an overview of the complete process. Selected steps are described in more detail. This will provide the detailed inputs, tasks, outputs, and examples for each activity in the step. The process includes issues related to distributed LVC environments using multiple distributed simulation architectures, live entities, and cyber.

The process described in this tutorial was developed to support distributed LVC Test and Evaluation. However, the process applies to research and development, training, and experimentation. This tutorial is beneficial for anyone involved in the integration and execution of large distributed events. The tutorial is particularly beneficial for engineers tasked with planning and executing distributed events. The tutorial does not require knowledge of the DSEEP standard. Integration and execution of large distributed Live, Virtual, Constructive (LVC) events consume substantial time.

Powerful & Accessible Immersive Experiences – Visualizing & Transforming Large Data Sets in eXtended Reality

Eric Martin, Peyton Bailey, JoAnn Archer, Claire Hughes

22T24

Extended Reality (XR) is the umbrella term that covers the technology stack of Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR). XR has seen rapid growth as a new medium for users to see and interact with data that would not be possible through traditional input devices. As adoption of

this technology grows, it will drive the need to visualize increasing amounts of data. One of the major challenges to large data visualization in XR is that it either requires a tremendous amount of processing power to fully visualize the content, or extreme scale cuts must be made to show such data sets on lower end hardware like mobile devices or head-worn displays. This tutorial will cover lessons learned in visualizing extremely large data sets using the Unity Real-Time Development Platform, including challenges of visualizing vast amounts of 3D data using the traditional Unity Game Object system, associated limitations, and how to overcome them with Unity's Data Oriented Technology Stack (DOTS). This tutorial will also provide a practical example to cover the visualization of publicly available 3D data from National Oceanic and Atmospheric Administration's Multi-Radar/Multi-Sensor System as a source, including the data extraction process, initial testing with Unity's traditional Game Object System, and the transition to the Unity DOTS that allowed for a jump from displaying a few hundred weather data points in 3D to over one million data points. This tutorial will also discuss the techniques that can be used to view and manipulate this data in XR along, with an evaluation of the benefits and limitations realized from utilizing the capabilities explored.

An Introduction to Cognitive Systems for Modeling & Simulation

Randolph Jones, Ph.D., CMSP, Dylan Schmorrow. Ph.D.

22T25

There is continuously increasing demand and enabling technology for automated reasoning abilities across the broad spectrum of training, simulation, and education, as well as in battlefield information, command, and control systems. Cognitive systems represent an approach to automation that "raises the bar" from data and information processing to robust, scalable, and adaptive decision making. This tutorial provides an introduction to cognitive systems, concentrating on high-level design and implementation patterns for human-like reasoning systems. We discuss the development cycle and the role of requirements definition for such systems, emphasizing that cognitive systems must encode not just WHAT decisions to make, but also WHY to make them. We draw examples and comparisons from existing cognitive systems, focusing on the tradeoffs between cognitive and non-cognitive engineering approaches. We focus on examples that highlight the differences between standard software engineering and a cognitive approach that uses "least-commitment reasoning". We then summarize the criteria by which one can decide which approach is more suitable for a particular problem. The tutorial content does not require any specialized knowledge, but some experience with software engineering or behavior modeling can be helpful. Attendees will learn to recognize problems that most benefit from cognitively based solutions, and they will be better able to assess risks, costs, and benefits of different approaches. This tutorial emphasizes reasoning systems, not learning systems, but it includes a discussion of how the integration of cognitive systems and machine learning can advance the future state of the art. This tutorial is targeted toward developers who might be interested in cognitive approaches to software engineering, as well as customers who have problems that may benefit from automation of reasoning and decision making.

Addressing the Challenges of Rigorous Model Validation

Simone Youngblood, Mikel Petty, Ph.D.

22T26

The process of validation is essential to the credible and reliable use of any simulation. Although Department of Defense policy and guidance increasingly emphasizes the importance of rigorous validation founded in the application of strong statistical analysis, implementation of rigorous validation continues to face multiple challenges. This tutorial will address several of those challenges:

- How to identify, collect, and combine validation referent data (what the simulation results will be compared to)
- How to identify the simulation measures and metrics to use as the basis of comparison (the aspects of the results that will be compared to the referent)
- Validation methods to apply when performing the results/ referent comparison
- Methods to evaluate the performance of selected validation methods
- How to quantify risk and residual uncertainty associated with the application of the simulation

The tutorial will enhance the learning experience by incorporating lessons learned derived from the many VV&A applications with which the authors have been involved.

Anytime, Anywhere Adaptive XR Training

JoAnn Archer, Frank Karluk, Claire Hughes

22T27

Training is often consumed in the classroom or remotely in a one-size-fits-all format with limited opportunity to practice hands-on skills in contextualized situations. Providing training which can be used anytime, anywhere and also offers the ability to "act out" or practice critical skills to instill muscle memory, embody actions, and employ critical thinking, is integral to trainees reaching proficiency. Virtual and augmented reality technologies are rapidly being adopted across the DoD for simulation, training, education, and operations, however, these component technologies are often used in isolation and require costly form factors. The benefits of these emerging technologies can be realized more fully by utilizing eXtended reality (XR), which blends a contextualized virtual environment with augmented overlays and real-world objects, on a cost-effective mobile device. When XR training applications are used, an opportunity exists to provide psychomotor practice in a highly engaging environment leading to significant gains in both primary and refresher training. Further, available evidence shows that when these XR training applications are adaptive, varying content and progression as a function of trainee proficiency, substantial gains in training efficacy are expected. This is especially evident when using artificial intelligence (AI) to allow the system to adapt training to the proficiency of the trainee, thereby enhancing training effectiveness and increasing field readiness. Providing trainees adaptive XR training anytime, anywhere using mobile devices enables consumption to be readily available and learner centered, offering an action-oriented supplement to typical classroom and remote training.

It is crucial when developing XR training solutions to evaluate the utility of the novel, contextually-based design elements and embodied interactions afforded by XR. Careful examination of these features can highlight positive and negative experiences in XR, possible improvements to usability, and future directions for evaluating the extensibility of contextualization and embodied cognition principles in the design of XR training solutions.

This Foundations Training tutorial will dive into the key elements of an XR training framework that leverages pedagogically based, formative assessments to infer trainee proficiency by providing insights into: key drivers of adaptive, accessible training in XR; potential barriers to embodied training; value-added case studies with end-user feedback; and user-centered guidelines for designing, developing and implementing mobile XR training systems. By the end of this tutorial, attendees will be able to implement effective techniques for adaptive, accessible XR training applications based on case studies of anytime, anywhere adaptive training being implemented for Tactical Combat Casualty Care training.

Secure Distributed Simulation Training Systems Anywhere, with OMG DDS

Robert Proctor, Jr., John Breitenbach

22T28

Integrating global simulation training systems can be a formidable challenge. Legacy simulators often use different standards for data, voice, and video. While modern architectures require the use of cloud-based distributed assets. To top it off, security requirements now force integrators to become experts in information assurance.

Winning solutions will be ones who create synthetic training environments that can quickly be assembled and reconfigured from ready-made components. How can simulation systems integrators keep pace by limiting integration time to meet these requirements? Attend this tutorial to learn how the Object Management Group's Data Distribution Service (DDS) can ease integration, while also delivering National Security Agency tested security for distributed training systems over any transport.

DDS is an open standard that provides interoperability through a connectivity framework that meets the stringent real-time requirements of global defense industries. DDS is currently used in over one thousand deployed defense systems, it seamlessly stitches together legacy defense simulations, while

adding humans and hardware in the loop, to create new secure LVC environments that can share real, augmented, and virtual realities. These environments run over DDS, either in a single lab or across multiple sites and transports, unifying disparate data models, all while enabling physics-speed response times.

This tutorial introduces the DDS and DDS Security standards. You will learn how to use the DDS Security standard to securely interoperate with real-world systems that already communicate over DDS, to distributed LVC Simulations. The tutorial will further describe how to integrate DDS with existing simulation standards, simulation object modes, and data models of any kind, allowing for a large suite of 'qualities of service' to help fine-tune performance and scalability, while also providing robust security for individual entities and topics of simulation data.

Next the tutorial will introduce you to the Real-Time WAN Transport that extends DDS capabilities to enable secure, scalable, and high-performance communication over WANs, TDL, RF and public 5G networks. The Real-Time WAN Transport uses UDP as the underlying IP transport-layer protocol to better anticipate and adapt to the challenges of diverse network conditions, device mobility, and the dynamic nature of WAN system architectures. Finally, the tutorial will highlight recent LVC Simulation user experiences with DDS and offer an overview of deployed systems using DDS in systems integration labs, and with LVC training simulators today.

This tutorial is intended for all audiences, though some familiarity with the basic principles of distributed computing is recommended.

Live, Virtual and Constructive (LVC) Interoperability 101

Kurt Lessmann, Damon Curry

22T29

The purpose of this tutorial is to provide managers the necessary insight needed to support intelligent decision making when employing LVC to solve their needs. The tutorial will discuss the various solutions and domains of the technology and how it can potentially support their LVC needs. The tutorial provides a relevant use case as the mechanism to explain the concepts and the solutions required to achieve success. The tutorial will not be an in-depth technology review of LVC interoperability yet will provide sufficient management-level insight into interoperability solutions and standards like Distributed Interactive Simulation (DIS), High Level Architecture (HLA), and the Test and Training Enabling Architecture (TENA) product line.

A History of Games for Military Training: From Sheep Knuckles to the Metaverse

Roger Smith, Ph.D., Peter Smith, Ph.D.

22T31

There is evidence of games being used for business trade, future prediction, and military strategy for at least 5,000 years. In this tutorial we explore the history of games as tools of military strategy, planning, and training from 3,000BC to the present. We reveal the long evolution of the basic components that are necessary to create a complex game. Concepts that first emerged in India and Asia at the end of the last millennia are still embedded in the games that we create today.

The tutorial has four major sections:

1. Ancient games from 3,000BC to 500AD, with a focus on the essential mechanics and the emergence of game pieces and rules.
2. Modern game design and early computer implementations from 500AD to 1980AD, in which the mathematics of wargames emerged and offered a format that was amenable to programming in the earliest analog computers of the 1940s through 1980s workstations.
3. Serious games and the recent embrace of the technology by military leaders at all levels. In these last forty years computer-based games have been transformed from crude experiments with the technology to a major workhorse for training in all domains and at all echelons.
4. Finally, we speculate on the possible future impacts of the metaverse, AI, and global mobile connectivity.

Sharing Environmental Data for LVC using RIEDP

Jean-Louis Gougeat, Farid Mamaghani, Christophe Rind

22T32

Data sharing for distributed simulation remains a difficult problem, especially when dealing with stovepipes or proprietary solutions. As a M&S standards development organization, SISO (the Simulation Interoperability Standards Organization) provides open and standardized solutions to address M&S data sharing issues.

Within SISO, the Reuse and Interoperation of Environmental Data and Processes (RIEDP) specifications simplify the terrain data sharing problems by providing standardized rules, methods, and clear semantics for exchanging data from key stages of the simulation terrain database generation process.

RIEDP concepts and components are embodied in two SISO products: the RIEDP Data Model Foundations and the RIEDP Detailed Features Description.

This tutorial provides an overview of the general terrain database creation process, how RIEDP solves the M&S terrain data sharing problem, and how RIEDP promotes reusability of database generation efforts, while leveraging commonly used GIS and simulation data formats. The tutorial focuses on the fundamental terrain/environment questions that LVC simulation federations have to address.

The key RIEDP concepts covered in this tutorial include the RIEDP Reference Process Model (RPM), the RIEDP Reference Abstract Data Model (RADM), and the use of semantic constructs and attributes to share and exchange environmental data. The tutorial will also highlight how existing formats are leveraged in RIEDP data sharing, data organization on media, use of dedicated metadata constructs, and a set of profiles for specific application sub-domains.

Evolution of RF Signal Visualization from Spectrum Analyzers to Augmented Reality

Jad Meouchy, Suzanne Borders

22T34

We are surrounded by invisible radio frequency signals created by human technology like radio and cellular. Traditionally, we see these signals through spectrum analyzers. However, the capabilities of existing analysis tools are being outpaced by the rapid modernization of wireless networks and topologies like 5G, IoT, and Bluetooth. RF is inherently multidimensional, but conventional analyzers display signals in 2D slices, limiting real-world applicability to highly technical users. Emerging technology that combines Augmented Reality displays and AI/ML algorithms is capable of spatializing RF data into its natural 3D location for easier understanding and communication.

This tutorial will provide an overview of the evolution of RF visualization tools from flat interfaces to immersive ones that can be used to discover and map RF signals and networks. The audience will gain a broad understanding of the emergence of immersive interfaces and how they can be applied successfully to spatial data visualization. Building upon proven UI/UX principles, we will walk participants through challenges with the design and development process, theory behind decisions, and usability issues to overcome in actual deployments. Resulting best practices will be shared openly. Finally, the audience will learn about future applications of these tools and forecasted innovations as the underlying technology matures.

Avoid the Illusion of Knowing: Reshaping Design in ADDIE

Patricia Mulligan-Renaud, Heather Seiser

22T39

Often training follows the process of receiving a topic/task list, writing learning objectives, developing lessons by copying in doctrine or regulation as content, writing test questions, and voila, the course is ready for implementation. What's wrong with this process? If you think about taking a boat ride, first we need to make a plan, launch the boat, map points of interest, refuel, stock supplies, and have experienced personnel steer the boat. Our training development processes need to be very similar to preparing for a boat ride. Following the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model is one way. We cannot stop at getting the boat in the water. What's the learning outcome? Did we design waypoints for learners to practice and get effective feedback? Did we apply scaffolding and

chunking? Did we design it for how we learn and how we retrieve learning to transfer to the performance environment? Or in our rush to get the boat in the water did we ignore the learning science that supports designing effective learning? When we skip design, we miss opportunities to create learning experiences that are effective, efficient, and encourage the deep learning required to meet mission readiness. So why do we skip or gloss over the design phase? Sometimes the illusion of knowing creeps into the decision making of inexperienced training developers or senior leadership. We make judgments about what good learning is by instinct and our own personal experience. Often these judgments have very little to do with how the brain learns or how learning theory is applied. Sometimes it is the result of the "that's the way we've always done it" syndrome. This can severely burden the unit level when we make poor design decisions. The goal of the tutorial is to help training developers, their supervisors, and anyone involved in the training development and decision-making process, design effective learning based on evidence from the learning sciences. This introductory tutorial will focus on the psychological and cognitive activities required for effective learning, present common learning myths that prevent us from creating efficient learning products, and provide design strategies that improve the relevance and rigor of the learning experience regardless of delivery method. When we do not use learning science, we only get the boat in the water; it never truly arrives at its destination, steering off course, and burdening another resource to rescue it when it is lost at sea.

Transform Your Training by Migrating Content to cmi5

Brian Miller

22T41

The learning and training landscape is changing rapidly with newer technologies emerging. While SCORM (Sharable Content Object Reference Model) has been the de facto eLearning industry standard, SCORM has not been extensible enough to support these technologies and does not provide enough guidance on capturing robust learner performance data.

Making the transition from SCORM to the more flexible Experience Application Programming Interface (xAPI) standard is key to supporting the vision and goals for modernizing learning within the Department of Defense while meeting the distributed learning policy (DoDI 1322.26) related to learning analytics and interoperability. SCORM and xAPI can be implemented together, but the divide is wide.

The cmi5 specification was modified in 2016 to help bridge the gap and define a set of rules for how online courses are imported, launched, and tracked using an LMS and xAPI. While cmi5 presents a promising solution, adoption across the DoD has been slow, but now there are tools and templates that are freely available from ADL to help migrate legacy content to the improved cmi5 specification.

In 2020, The Advanced Distributed Learning (ADL) Initiative awarded Rustici Software a contract to design and build tools to aid in the adoption of cmi5, including sample cmi5 course templates to aid in converting legacy content and a cmi5 Content Test Suite, known as cmi5 Advanced Testing Application and Player Underpinning Learning Technologies (cmi5 CATAPULT).

This tutorial will help attendees better understand how to utilize cmi5 and the freely available course templates from cmi5 CATAPULT to migrate, create and test their courseware to ensure they conform to the cmi5 specification. After an introduction to cmi5 and why eLearning standards are a necessary component of modern learning ecosystems, the tutorial will walk attendees through converting legacy SCORM content to cmi5 using the cmi5 course templates as well as describing the importance of testing in ADL's cmi5 Content Test Suite.

The cmi5 specification plays an important role in the DoD's learning modernization, facilitating progress in migrating from SCORM-based LMS-centric courseware to a distributed learning "ecosystem" that delivers diverse learning opportunities across federated platforms. With the cmi5 Conformance Test Suite and cmi5 example course templates, there are now ways to validate that content conforms to the cmi5 specification and migrate existing courseware, which will help increase adoption of the specification and move toward the DoD's Total Learning Architecture goals.

Leading by Design: User Experience (UX) for the Department of Defense

Amanda Hawkins, Vel Preston

22T43

As data and technology become increasingly intertwined in everything we do, User Experience (UX) design - the intentional creation of an experience that offers utility and value to the end user - is even more critical to mission success for our warfighters. In the military, poorly designed experiences, often involving software, processes, and tools - those with "bad" UX - have critical consequences for our warfighter. Bad UX serves as a detriment to battlefield outcomes and mission success, overloading warfighter processing capabilities, introducing errors into the mission, and potentially compounding those errors to such an extent that it results in mission failure and loss of life.

In the modeling, simulation and wargaming communities, good UX can help:

- Generate requirements for products that are based on end user input
- Iteratively design and test experiences with end users
- Focus solutions on solving the right problem and avoid over-engineering solutions that are solving unnecessary problems

This tutorial will explain the UX design process and explain how it reduces overall risk to delivery. Participants will also learn how incorporating UX design principles ensures the output of modeling and simulation is aligned to the intended application.

This tutorial is for those interested in understanding the basic principles of UX and how these principles can be applied in processes like waterfall and agile within the modeling and simulation and the U.S. Government. Project managers, software developers, and anyone who wants to deliver better experiences to the warfighter should attend. A knowledge of training is recommended but no background knowledge of UX is required to fully participate in this session.

Introduction to Competency-Based Experiential Learning

Kevin Owens, Benjamin Goldberg, Ph.D., Shelly Blake-Plock, Robby Robson, Ph.D.

22T44

All performance related to military and workplace functions require repeated practice under varied conditions to truly learn and maintain competence in work related tasks and duties. As has been practiced and studied for over a century, the process of building real workforce experience that is suggested to account for 70% of effective transfer of any knowledge, skill and/or the affective traits needed in a work environment has been a gap in most formal programs of education and training today. This process involves deliberate drills, assessments, feedback, reflection and the rapid re-design of exercises (experiences) that develops key work-site task-competence at level of difficulty that matches the zone of proximal development of the actor (team or individual). This is what's called competency-based experiential learning (CBEL). This tutorial will provide an introduction to CBEL and provide the presenters' unique insights into the need, the theory and principles, the components and processes for CBEL. Materials presented draw upon the presenters' involvement in previous DoD projects as well as developing the US Army's new Synthetic Training Environment (STE), and in particular, the STE Experiential Learning for Readiness (STEEL-R) research project. This will be shown in a demonstration of the current STEELR project.

Principles for Designing Effective, Efficient, and Engaging Training to Accelerate Expertise

Mohammadreza Jalaeian, Ph.D., Joseph Borders, Emily Newsome, John Schmitt, Gary Klein

22T45

Good instruction should be effective, efficient, and engaging (e3) and be based on tasks that fit together to solve real-world problems. However, more often than not, only two priorities can be accomplished at the expense of the third. On the other hand, from surgeons to teachers to warfighters, performance is more complex and more scrutinized than ever. While the systematic design of instruction (SDI) supports the creation of training programs that can move many performers to certifiable competence, it has less to offer the progression from competence to proficiency and expertise. Although enabling effective,

efficient, and engaging learning is a priority concern for practitioners and researchers in many performance domains, it remains a constant challenge for instructional designers to create training programs that accomplish all three and at the same time accelerate the development of performers to higher levels of expertise.

This tutorial addresses this challenge. It provides an overview of the systematic design of instruction components as well as expertise studies, specifically the findings from Naturalistic Decision-Making research. The presentation will review the cognitive aspects of learning (such as diagnosis, sensemaking, decision-making, and immediate feedback) to facilitate rapid learning and specifically guide mental model development. It will address the application of these cognitive aspects to the design and development of part-task training programs. The presentation will discuss a scenario-based method of training emerged from Naturalistic Decision-Making research that allows trainees to practice some of these complex cognitive skills and learn from an expert without an actual expert being present (effective) and in a highly accessible (efficient) and engaging environment.

This tutorial is for those interested in using systematic design of instruction model to create training programs and learning technologies that will accelerate expertise. Participants will learn about each component of the SDI model and how theories and methods of the Naturalistic Decision Making can be incorporated to build better training. Trainers, learning developers, instructional technology managers, training managers, researchers, educators, commanders, and decision makers should attend.

Learning Objectives

- Learning components of the systematic design of instruction model.
- Learning different types of knowledge and skill development stages.
- Learning the Naturalistic Decision-Making approach and tools.
- Appreciating the cognitive dimension and mental model development.
- Learning scenario-based method of effective, efficient, and engaging training to accelerate expertise.

Operational Impact: Quantifying Training Solution Value

Kelly Hale, Ph.D., Amy Taber

22T46

The goal of training is to establish or increase knowledge and performance of skills, with improved performance realized in an operational setting. But quantifying the impact of training in operational terms is oftentimes seen as unachievable. Stakeholders are left to make acquisition decisions based on requirements met, not on how much of an impact a given training solution will have on operations.

By starting with integrating clear measures of operational impact right at the beginning of an agile product development lifecycle, insightful supporting and transfer documentation can build knowledge and skills based on clear objectives that directly leverage those measures of impact. This can then be assessed in an incremental approach, and the documents become readily adaptable to formal training requirements.

Implementing the key steps, one can best quantify the learning impact on the individual, team and organization. (1) Clearly define the identified performance gap in terms of operational impact; (2) develop impact-based learning objectives to address the gap, and (3) establish clear metrics to measure achievement of learning objectives and anticipated performance outcomes. To be successful, evaluating operational impact requires a transparent upfront needs analysis.

Using Kirkpatrick's model of training evaluation can help to ensure operational impact is evaluated across all four evaluation levels: Reaction (Was the training well received?); Learning (Did the trainees learn?); Behavior (Did this learning result in changed behaviors/transfer of training?); Impact (Did the training make the desired organizational impact?). Through this Operational Impact Analysis, one can align business indicators with skills/knowledge gained, and provide quantitative validation that training will have the desired impact. Stakeholders want to see impact in terms of time, lives, or money saved. Incorporating user-in-the-loop evaluations implementing key metrics of success during early product releases can provide operational impact indicators, and not only show the potential value of the training solution, but also guide development in identifying opportunities for increased training transfer capabilities, often in a more compressed timeline to sustainment.

This tutorial will provide attendees with insights on why Operational Impact is critical for training success, and how measuring Operational Impact can be integrated into the training development process. Implementing methods of evaluation can provide attendees with a means to formulate outcomes that will more clealry demonstrate the value and impact of their training solution - not only with initial knowledge and skill transfer, but also the overarching beneficial impact to the program office and organization.

IEEE 1278TM Standard for Distributed Interactive Simulation (DIS): Concepts and Techniques

Robert Murray

22T51

As any gamer will tell you, it is compelling to connect simulations and play with other actual human participants, whether in the next room or on the next continent. The seminal development of simulation networking in the 1980's connected Army tank training simulators, enabling them to interact over local and wide area networks.

The desire to expand this to all military training and engineering simulations resulted in a large government, industry, and acedemic effort to standardize the network protocol for simulation interoperability. Distributed Interactive Simulation (DIS) was the result, using the IEEE standards process to create technically sound and widely accepted protocol to link military training and engineering simulations. IEEE 1278TM-1995 and additions in 1998 were the first full DIS standards that contained the protocol and rules for real-time simulation interoperability of military land, sea, and air platforms, weapon interactions, radar, radio, IFF, laser designators, underwater acoustics, logistics, simulation management functions, and more.

The success of DIS expanded into the Simulation Interoperability Standards Organization (SISO) in 1996. SISO took over the development of the DIS standard and launched a wider range of simulation standards. Work in the 2000's developed the next round of improvements of DIS, resulting in IEEE 1278.1TM-2012. Continued development within SISO is working toward the next version, referred to as Version 8, expected to be completed in the mid-2020's.

This tutorial explains how DIS achieves real-time high-fidelity interoperability over best-effort networks. The basic concept and some of the technical details will be introduced to give students a foundation for starting and expanding the implementation and use DIS in their simulations. The standards process, history, and future directions of DIS are also presented.

Secure Private Wireless Network Architecture Applied to LVC Environments

Jason Hester, Andrew Stewart

22T53

More expansive LVC training requirements mandate an increasingly expansive and broadly connected network - connecting many users/devices to data and applications. Users/devices interact with data and applications via a network that spans from edge to cloud. The underlying architecture must enable integration of many types of live and virtual connected systems, connection of users/systems from multiple locations, and means to connect users/devices of differing characteristics (e.g. mobile, fixed, low-latency demand, constrained bandwidth). The employment of a private wireless architecture in the demanding LVC environment manages complexity while optimizing performance and security. A private wireless architecture delivers the desired connectivity and performance that enables the entire ecosystem (edge-network-datacenter-cloud) to operate as an integrated, secure LVC training platform. This approach also allows for a Zero Trust Architecture (ZTA).

A private wireless architecture brings together wired and multiple wireless access technologies such as LTE, 5G, Wi-Fi 6, LoRaWAN, Ultra-Reliable Low-Latency Communication (uRLLC), and massive Machine-Type Communications (mMTC). The role of the network architecture is to provide secure connectivity between all nodes - most especially ensuring seamless wireless connectivity for mobile nodes. ZTA is an increasingly critical approach to any network architecture employment and can be applied to an LVC wireless environment. ZTA spans across all components of the LVC Network

including training participants and support, user/device connections and connection of data and applications no matter how they connect to the network and associated resource.

Greater adoption of wireless technology by the Department of Defense creates a revolutionary shift for IT operations that the LVC training environment should embrace. These technologies enable operators to exchange data at greater speeds, over increased bandwidths, with secure connectivity, and in support of ubiquitous access methods. LVC training must enable new transformative mission threads and potentially allow for the experimentation of the consumption of the features offered by these mediums while remaining aligned with training objectives. These developments necessitate that the underlying network provides the LVC the ability to host applications using wireless technologies.

A ZTA enables users, devices, and applications to exchange data while integrating into data centers and edge distribution nodes; all based on least-privileged access principles. Integration of massively scalable, low latency-enabled applications opens new mission capabilities and creates new demands on the LVC environment. A comprehensive private wireless architecture able to leverage diverse mobile/fixed connectivity requirements at the edge, with ZT security incorporated, provides the full potential of the LVC environment, ensuring mission success.

Machine Learning and the Benefits of Applying it to XR Training Systems

Adam Kohl, Eliot Winer, Ph.D., Roselynn Conrady

22T54

As in many other industries, the use and spending of machine learning (ML) technologies has drastically increased for the Department of Defense. Contract spending for 2019 yielded $973 million for ML related projects and is projected to rise to $2.8 billion by 2023. ML methods and technologies have existed for many years but have quickly become critical in fields such as engineering, medicine, and consumer services. Recently, ML has found enormous benefits in XR-enabled environments used for a variety of purposes such as product and process design as well as training. Understanding the vast field of ML and its specific application to training systems can be extremely challenging. Miscomprehension can lead to poor management and development activities that will result in more costly and disappointing training solutions. Understanding the fundamentals of ML, and its application to Extended Reality (XR), will empower managers to make appropriate strategic and costing decisions and allow designers, developers, and engineers to successfully implement effective training systems.

This tutorial provides an overview of ML technologies from early research to today's modern algorithms. This tutorial will include how ML can be combined with XR environments to fundamentally change how humans interact with training systems. The presentation will review how specific ML and XR tools can produce more immersive training solutions while providing deeper insights from a variety of data that can be collected and analyzed about trainee performance. This tutorial will also present examples demonstrating ML's use in designing, testing, and optimizing XR training systems and evaluate the efficacy of incorporating this technology to aide in warfighter training to improve efficiency, reduce costs and training time.

This tutorial is for a wide range of stakeholders from those interested in gaining a basic understanding of ML for administrative level decision making to those who want detailed methods and integrations within XR-enabled training environments to gain specific performance improvements.

International Trade Compliance: Regulatory Developments and Key Risk Areas

Adelicia "Addie" Cliffe, David "DJ" Wolff

22T56

In this session, we will provide a basic overview of the key export control regimes, the International Traffic in Arms Regulations (ITAR) and the Export Administration Regulations (EAR), as well as the economic and trade sanctions programs administered by the Office of Foreign Asset Control (OFAC). We will provide an explanation of how to determine what controls and authorization requirements apply to particular activities and transactions, and when and how defense contractors may be able to leverage exemptions from the licensing requirements. We will talk through recent regulatory changes and the practical impact of those changes, and provide tips for best practices on risk mitigation in this space.

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