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BEST PAPER

Enhancing Naval Enterprise Readiness through Augmented Reality Knowledge Extraction

Victoria Claypoole, Christina Padron, Kay Stanney, Ray Perez
20314

The newest wave of Naval aircraft carriers are implementing novel systems that require fewer Sailors to man, with the goal of improving readiness and reducing operating costs. These new, unique systems has led to an increase in required training hours for Sailors. To address this gap, recent developments in Naval training have included the use of emerging technologies, like augmented reality (AR), to support high velocity learning in traditional school-house and pier-side learning environments. However, what is still lacking is the ability to transition this technology to on-the-job training in the form of job performance aids (JPAs). Due to the reduced-crew environments of the new Ford-class carriers, expert Sailors have less time available to mentor and coach junior Sailors. Thus, a gap exists in utilizing emerging technologies to assist both expert and junior Sailors as they are underway. The present paper discusses the application of AR for the extraction of expert maintainer knowledge, allowing the Navy to capture expert maintainers' hard-earned expertise and then store and distribute their knowledge and skills for life-long Naval enterprise use. This allows junior maintainers to "take experts with them", as they need support in their work, long after those experts have retired. This paper discusses the development of such an application, evaluation onboard the CVN 78 with Machine Control Monitoring System (MCMS) maintenance technicians, and concludes with a summary of initial lessons learned and future directions and applications onboard the CVN 78.

Leveraging HPC Techniques for Large-Scale Agent-Based Models in Python

Melonie Richey, Zachary Mostowsky
20210

Agent-based modelling (ABM) and simulation is a domain of social simulation that provides the following benefits: 1) the ability to model individual-level decisionmaking regimes across many millions of agents, 2), the ability to create spatially-explicit simulations, and 3) the ability to observe simulated behavior at the individual level or in aggregate. As ABMs reach massive scale incorporating many millions, even hundreds of millions, of individual agents, compute and model run time quickly become the bottleneck for more robust simulation. ABMs are traditionally difficult to parallelize through standard techniques such as multiprocessing and multithreading due to the need for a shared memory environment. Communication between agents at every time step is intensive and agent decisionmaking at the individual level is based on 1) the actions of other agents, and 2) the state of the environment at each time step. While packages exist to parallelize ABMs in C++ or Fortran, fewer approaches are available in Python and using cloud-based resources. This paper will detail the process of paralellizing a large-scale, spatially-explicit ABM simulating ~8M agents on Google Cloud Platform (GCP). The agents represent refugees in response to forced migration events worldwide.

Real-time simulation of crowd disasters

Christoph Luerig
20216

In this paper, we explain a crowd simulation technique that allows real-time simulation of crowds, mainly for evacuation scenarios. Crowd disasters with deadly accidents often happen in places with high people density, sometimes in combination with additional factors like fire or terrorist attacks. Having an interactive simulator for these phenomena offers the possibility to create a planning tool and to create an educational simulation that explains the essential dynamics of crowd disasters.

The approach is based on the simulation of crowd density and gets modeled by a partial differential equation. In contrast to an agent and particle-based simulations, this approach works with a minimal set of assumptions and is easy to parallelize on the graphics card in CUDA.

We base the simulation model on three assumptions. The first assumption is that everybody tries to get to the next exit in minimal time. This decision is made purely on the current situation, and no prediction about the future is involved. This assumption is modeled with the Eikonal equation. The second assumption is a relation between people density and magnitude walking velocity of people in crowd situations. This relation has been published. The third assumption is that the amount of people except for intentional spawning and despawning stays constant. The continuity equation expresses the third assumption.

To validate the model, we demonstrate its capability to replicate several known effects, which include density clogging in corner situations, shockwave propagation effect once the density has reached 5-6 persons per square meter, and the effect of abruptly narrowing corridors.

The simulation core is open source under the MIT license and available on GitHub on https://github.com/Carbonfreezer/PanicSimulator. Several screenshots and videos are available on the attached wiki.

Optimal Image to Lidar Deep Learning Regression for Height Estimation

Mark Rahmes, William Watkins, Glenn Boudreaux
20229

We describe a system for estimating pixel heights from a single multispectral RGB image with or without sensor metadata information. System components include an ensemble of multiple convolutional-deconvolutional neural network (CNN) models and an optimization function. The chosen deep learning network model per pixel is validated using high resolution aerial RGB imagery and lidar data sets. A data knowledge base provides historic time stamped multi-modality data for registration and 3D feature classification. Given a large amount of elevation truth data, a model is trained to recognize image features of differing heights using CNN image to lidar regression. The models, when applied to an unseen image, estimate a preliminary height per pixel, based on learned feature set. Multiple models are created and trained end-to-end and best model and result are determined. We use linear programming optimization with an ensemble of regression models and semantic segmentation information with a CNN classification model to decide optimized pixel height estimates. Semantic segmentation data sets help classify RGB imagery with feature class labels and refine land use feature classification with CNN classification to improve accuracy. Each land use classified feature can be weighted with a confidence metric which is used to help determine height information. Therefor we use CNN regression for preliminary height estimation and CNN classification for land use feature classification plus a linear programming reward matrix per pixel to automatically decide optimized height estimation. The rows in reward matrix contain CNN regression model results from image to lidar regression, while columns contain CNN classification model results from RGB imagery. An updated volumetric knowledge base contains the system output and is further used for change detection and situational awareness. Both qualitative and quantitative analysis are performed and visualized.

Optimal Deep Learning Signal Classification with Wavelet Compressive Sensing

Mark Rahmes, Thomas Billhartz, David Chester, Chad Lau
20231

We describe a cognitive system for recognizing and classifying radio signals by modulation type with various signal-to-noise ratios. System components include an ensemble of convolutional neural network (CNN) machine learning models, wavelet compressive sensing, and an optimization function. The chosen deep learning network model per signal is validated using a DeepSig data set consisting of 24 digital and analog modulation over the air recordings. Given a large amount of signal truth data, a model is trained to recognize features of differing modulation types using different supervised gradient learning algorithms with CNN based classification. The models, when applied to unseen signals, estimate a preliminary modulation based on a learned feature set. Multiple models are created and trained end-to-end and the best model and results are determined. We use linear programming optimization to determine the best model from an ensemble of classification models. With increasing growth of technology, there is a higher demand to compress, handle, and encode more information using fewer bits. Digital information must be stored and retrieved in a highly efficient and effective manner while reducing the data redundancy to save hardware space and transmission time. The Discrete Wavelet Transform (DWT) provides a mathematical method of encoding information in such a way that it is layered according to level of detail. This layering produces approximations and details at various intermediate stages and facilitates less storage space than the original signal data. We use a complex 1D signal compression method, using the Haar wavelet with perfect reconstruction, as the basis function. The effect of deep learning classification using wavelet compressive sensing for signal classification is quantitatively shown with accuracy performance curves. Our

approach results in higher accuracy and precision when compared with individual machine learning algorithms alone.

Optimizing Feature Selection for Semi-Supervised Machine Learning Classifiers

Anastacia MacAllister, Jordan Belknap, Danielle Clement, Megan McConnell, Stephen Summers
20237

In 2018 the United States Department of Defense (DoD) released their Artificial Intelligence (AI) strategy summary. The report highlights several key AI technologies the nation needs to maintain a competitive edge. The DoD asserts that one such area, AI based predictive maintenance, is integral to ensuring equipment like aircraft and armored vehicles stay mission ready. Unfortunately, the DoD maintains varied fleets of equipment, often at lower quantities than commercial industry. These small quantities of equipment at varying operating conditions makes collecting representative data sets, often required for AI, challenging. Another factor, complicating the creation of AI for military applications, is the lack of insight into which variables best capture complex processes. This can make it challenging to determine which variables are important factors to include in an AI model.

While SMEs often provide insight into data, they may not identify the optimal combination of features. There could be bias in the SMEs recommendation, or for security reasons they may not know the true nature of the variables. As a result, another method of selecting optimal features for AI models is needed. While existing literature contains ample work on feature selection, only limited work exists dealing with small data sets. This paper describes work using Binary Particle Swarm Optimization (B-PSO) to optimize the accuracy of a Self-Organizing Maps (SOMs) based AI model for predictive maintenance trained using a small real-world data set. Testing results show that using B-PSO to select training features produces a classifier with up to 95% accuracy, 98% precision, and 72% recall. This new method increased some AI model accuracy metrics by 23% over the original baseline. The final paper will describe the novel algorithm, present testing results, and describe how this method can be used by the broader community to help increase AI model accuracy.

Evolved Artificial Intelligence for Stochastic Clustering Unsupervised Learning

Randal Allen
20258

Using mainstream AI/ML algorithms, entire classes of practical use cases are doomed to be computationally intractable or require many multiple universe-lifetimes of data collection. I/ITSEC paper 19149 (Allen) introduced an innovative architectural approach to AI where neural sigmoid functions are replaced by mathematical models of arbitrary complexity, thus collapsing net sizes and depth, and ultimately reducing computational and data requirements. Without the constraints imposed by neural assumptions, mathematical models may be nonlinear and/or discontinuous and may be guided by human knowledge of the system. This novel approach, along with advanced optimization methods presented in I/ITSEC paper 19109 (Allen), forms the basis a new family of Evolved AI solutions.

During a National Defense (January 2020) interview, NDIA's Senior Fellow for AI expressed how algorithms and framework have evolved beyond supervised learning into unsupervised and reinforcement learning. Having presented the algorithms and laid the framework for Evolved AI, the focus of this paper shifts to applications of this emerging technology to stochastic clustering.

The paper first describes how the laptop-executable approach combines elements of both hard and soft clustering without the need for cleaning/scaling data, nor the need for training data. Unlike k-means and k-medoids, the cluster number (k) is not needed a priori, as with hierarchical clustering. By leveraging fuzzy c-means and Gaussian mixture models, data points may belong to more than one cluster having different sizes and correlations. Overall, cluster number is adaptively determined from the distribution of resultant cluster permutations.

The paper then presents and discusses an example in the context of pulse spectrum analysis where preliminary work in applying multi-dimensional stochastic clustering has proven successful.

Upon summarizing results, the paper concludes by recommending applications of this emerging technology to Training and Education, for example measuring pilot training exercise data and clustering results in terms of ideal execution.

Utilizing Satellite Imagery Datasets and Machine Learning Data Models to Evaluate Infrastructure Change in Undeveloped Regions

Ryan McAlinden, Kyle McCullough, Meida Chen, Andrew Feng
20269

In the globalized economic world, it's become important to understand the purpose behind infrastructural initiatives occurring within undeveloped regions of the earth, especially when the financing for such projects must be coming from external sources. Global coverage from a large number of commercial, private, and government satellites have produced enormous imagery datasets. Thus, these geospatial resources can be easily mined and processed using machine learning algorithms and neural networks. Increasingly beneficial is the fact that this data is available in largely undeveloped areas where ground or aerial coverage is either non-existent or not commonly acquired, such as major portions of the African continent. Although the advantages of such easily accessible, large datasets are substantial, the downside is that a majority of these geospatial data resources are in a state of technical static, as it's difficult to quickly understand the importance of a particular image from the moment in time it was taken. This work seeks to leverage portions of the Author's previous work presented at I/ITSEC 2019, for fully automated data segmentation and object information extraction framework for creating simulation terrain using UAV-based photogrammetric data (Chen et al. 2019) by extending some of the feature classification methodology to satellite imagery, with a focus on change detection in large-scale human construction and development, such as railroads. This research hopes to evaluate specific events over time that are easily and rapidly detectable. While we will utilize existing architecture from our current methods, a new set of training data will be produced from satellite imagery for detecting this infrastructure. A goal of this research is to allow automated monitoring of change over time for large-scale infrastructure projects to best determine reliable metrics that define the scope and scale, as well as the future direction these construction initiatives could be expected to take.

Evaluating the Use of Augmented Reality for Aircraft Maintenance Training

Charis Horner, Christina Padron, Troy Westbrook
20292

Maintaining aircraft within the Air Force remains the key to being mission ready. However, as the fleet continues to age, the average mission-capable rate across the fleet has steadily declined, dipping below 70% in fiscal year 2018, the lowest in six years. The older fleet requires additional inspection and maintenance, and the Air Force has named potential solutions such as less depot-based maintenance and more flight line maintenance, and more condition-based maintenance rather than preventative. There also remains a shortage of experienced maintainers, as the recently closed manning gap resulted in an overabundance of 3-level maintainers and a shortage of 5 and 7 level maintainers. Air Force Secretary Wilson said it herself, "Readiness is first and foremost about training people." Air Force Training Support Squadrons (TRSS) are tasked with creating this training. This paper is a follow up to previous work in which AR was utilized for content creation of maintenance training (Padron et al., 2019) by detailing the next step in that evaluation, where training content was piloted on the flight line in conjunction with the 367 TRSS and C-5 maintainers out of Travis Air Force Base. Results will be discussed, including best practice recommendations for authoring and use of AR in Air Force flight line training, and analysis of suitability of AR for rapid content creation and advancing maintainer skill proficiency.

Utilizing Physical Props to Simulate Equipment in Immersive Environments

Jason Jerald, Jason Haskins
20322

Next-generation tools have the potential to significantly enhance our abilities to perform tasks in the real world. However, since early prototypes of such tools are at an early experimental stage, they are not yet ready to be used or fully tested. Even when the prototypes are refined, it can be difficult to evaluate and optimize their use in the context for which they will be deployed. To propel tool development, evaluation, and usage, we are leveraging virtual reality (VR) technologies to efficiently test simulated prototypes of new tools in virtual environments that simulate the context in which they will be used.

Whereas consumer VR systems can support scenarios that are quite visually and aurally realistic, most of today-s VR hardware is lacking when it comes to using physical tools. This shortfall is especially critical when simulating real-world user interfaces and the real physical world we work in. We describe here how we are enhancing (and evaluating) VR interfaces and simulated immersive environments with realistic physical cues for firefighters, law enforcement, and paramedics. Work includes integrating physicality into VR simulations by building customized tracked devices and evaluating how adding such physicality to VR results in performance closer to real world performance.

Can real-time Artificial Intelligence techniques be applied to Synthetic Environments?

Graham Long
20327

The increasing proliferation of source data poses a significant challenge to the capabilities of Synthetic Environment (SE) generation pipelines to transform this data with the necessary agility, velocity, productivity and affordability required to meet future demands.

Previous research has demonstrated the potential to apply Artificial Intelligence (AI) throughout the entire generation pipeline. But the ability to capture large volumes of imagery, video, point cloud and other real-world data within days, hours or in real-time places specific demands on the capacity of SE pipelines to extract and process features, attributes and properties from this data, and update or create SE's at a comparable tempo.

Faced with a similar and potentially overwhelming data glut, fields such as security, autonomous vehicle and Intelligence, Surveillance and Reconnaissance (ISR) systems are performing automated, real-time analysis and computer vision tasks, from facial recognition and human pose estimation to object detection, classification and segmentation. These are made possible by the application of AI, particularly Deep Learning (DL), to perform critical data processing and analysis in real-time, often on edge devices.

If similar techniques can be applied to SE generation it offers a path to genuinely rapid SE construction. Today's largely offline data preparation and processing tasks could be encapsulated into a pipeline that can intelligently analyse, process and exploit input data, extract features, derive and generate content on-the-fly, in an end to end, data to run-time SE construction process.

This paper will examine the state and application of AI to rapid or real-time data processing and analysis. It will assess if, how and where such implementations of AI and DL could be applied to introduce similarly fast, dynamic data exploitation into the SE pipeline, and consider potential issues such solutions may pose in areas such as SE interoperability.

Proactively Suggesting Similar Past Stories Turns "Lessons Learned" Into "Lessons Used"

Eric Domeshek, James Ong, Daniel Tuohy, David Spangler, Thomas Williams
20337

The most common failing of existing lessons learned libraries is that important experiences are stored, but then are rarely retrieved when they might usefully inform decision making.Searching for lessons in existing systems is often seen as an inconvenient, time-consuming disruption when pressing decisions need to be madeWe describe an approach to proactively providing decision advice by extending task support tools to automatically formulate queries against a repository of past experiences.Retrieved texts are offered in context to minimize disruptions and maximize connection with ongoing work.Rather than depend on traditional text-based indexing and retrieval, we experimented with matching structured representations of a current problem/solution, pulled from decision-support tools, against narrative structures extracted from experiential texts.

We built a prototype system to support operational planners working on counterinsurgency and Stability, Security, Transition and Reconstruction (SSTR) operations.As an exploration of what an ideal information extraction system might usefully produce, we had subject matter experts select and annotate two-hundred experiential texts containing potential planning lessons.We then had a panel of forty-nine active duty and retired officers attempt mission planning exercises using a simple web-based planning tool enhanced with our automated lesson retrieval scheme.

On the specific question of whether the system could improve plan quality, a paired t-test on the users' self-ratings of plan quality across two plans—one developed with advice retrieval support, the other without—showed a small but significant increase in self-ratings of plan quality.In opinion surveys: 69% of evaluators agreed that the system helped with planning; 92% agreed that the concept of experiential advice is valid and potentially useful for military planners; 88% agreed that the system should be further developed; and 82% agreed that work on the integrated planning tools should be continued.

Trusting a black box: explaining complex simulation outcomes using LIME.

Stefano Romano, Christoforos Anagnostopoulos
20349

The field of Artificial Intelligence (AI) has recently been suffering an "interpretability crisis": black-box techniques like deep learning produce impressively accurate predictions, but fail to offer any human intelligible explanation, making it hard to establish their safety and fitness-of-purpose in highly regulated or safety-critical domains.

In the adjacent field of modelling and simulation, this challenge is not new: complex simulations generate emergent outputs via the interaction of a vast amount of dynamic components, which can make the system as a whole opaque to the user. Additionally, their complexity typically renders these simulations sensitive to initial parameter settings or details of their initial state such as the exact placement of units on a map. This can be broadly quantified via classical techniques such as sensitivity analysis, which however fail to provide a true explanation of simulation outputs in terms of understandable features of the input space.

As a response to the interpretability crisis in AI, the new field of Explainable AI (XAI) has emerged in recent years. Techniques like Locally Interpretable Model Explanations (LIME) enable powerful post-hoc analysis of predictions that provides an intuition for the model's logic. This is achieved by considering how small, local changes to the input configuration affect the response, capturing the resulting dependencies using interpretable statistical techniques, and reporting them in an intuitive graphical user interface. This closes the loop between the model and the user, allowing the user not only to build trust in the model, but also to actively improve it by identifying blind spots and misconceptions that are evident to a human expert.

In this work, we investigate the applications of XAI techniques to complex simulations. In a series of examples from the social sciences and operational research we use LIME to coherently trace emergent patterns back to the input space.

Machine learning surrogates for highly realistic simulations

Patrick Cannon, Rory Greig, Christoforos Anagnostopoulos
20375

High-fidelity simulations of real world systems such as traffic, physical infrastructure and the civilian population are the next frontier in improving the depth and sophistication of military simulations. Such complex systems are difficult to model with complete accuracy, and often involve unobserved free parameters. To make these simulations as realistic as possible, these parameters need to be tuned by matching the simulation output to real world data collected from these systems in a process known as "calibration". Typically, calibration is approached via brute force exploration of the parameter space in an attempt to identify the parameter setting that best reproduces patterns seen in real-world data or ascertained by subject matter experts. However with large numbers of parameters and computationally expensive simulators this quickly becomes intractable.

In structural engineering and elsewhere, this problem is often overcome using "surrogate-based" optimisation, wherein a computationally efficient surrogate model is trained on sample input-output pairs from the simulation, and is thereafter used for rapid parameter exploration. Candidates for surrogates have included machine learning models like random forests and deep nets, as well as interpolation-based techniques like kriging - the latter gives rise to a suite of tools known as Bayesian optimisation. Surrogates can be trained sequentially, in a process known as "active learning": the next configuration is picked so as to maximise its information content, exploring the space sufficiently while still converging to the area that has so far produced the best answers.

We illustrate these techniques for the first time on a challenging calibration problem in traffic micro-simulation, using the industry-standard open-source simulator SUMO. Using real-world observed traffic data as our target pattern, we sequentially fine-tune SUMO's initial state and configuration parameters to maximise the fit to the target pattern, resulting in a far more realistic simulator than that obtained with manual or brute-force fine-tuning.

Measuring Dynamic Occlusion Performance in Augmented Reality Training Systems

Michael Martin, Juan Castillo, Scott Johnson, Jaime Cisneros, Kiel Ewing, John Baker, Patrick Garrity
20386

Augmented Reality (AR) is rapidly maturing, and as this it develops, it will present the training community with unprecedented capabilities. However, there remain several key technical challenges that must be addressed in order to deliver credible and immersive experiences. At the Training & Simulation Industry Symposium 2019 and in subsequent public forums, the Simulation & Training Technology Center identified Dynamic Occlusion as a key technological challenge critical to the successful implementation of AR applications and specifically critical to AR training. Dynamic Occlusion is the ability of an AR system to realistically spatially integrate synthetic and real-world content. Dynamic occlusion allows moving real-world objects, such as people, to occlude virtual content in a credible and natural manner. For

example, if a person walks in front of a synthetic box, the person should occlude the box and the box should not be visible "through" the person. This concept is intuitive to observers, but there currently does not exist a commonly understood metric for measuring dynamic occlusion performance of various AR systems. In this paper, we propose a metric for assessing Dynamic Occlusion and break Dynamic Occlusion down into constituent factors of false positive and false negative occlusion. We will discuss the relative merits and challenges of these differing types of occlusion and their ultimate effect upon user acceptance and suspension of disbelief in AR experiences. We will also discuss recommended methodologies to gather Dynamic Occlusion metrics over a variety of conditions. The intent of this work is to provide a common conceptual framework that can facilitate the establishment of requirements as well as objective comparisons of performance across various systems. This framework will allow solutions to be accurately compared as we collectively tackle this key technical challenge to the implementation of AR training systems.

Teaming Artificial Intelligence with Digital Twins to Improve Training Effectiveness

Evan Oster, Jeffrey Beaubien, Zach Smith, Viviana Kypraios
20433

There are numerous factors that can diminish the effectiveness of training within the military. Until recently we have often thrown away or passed up valuable data that could have provided massive advantages when making training decisions.

This brings up the question, can training effectiveness be improved through the implementation of a new data strategy approach that complements existing training? Developing training from scratch is time demanding, labor intensive, and costly. However, teaming Artificial Intelligence (AI) with the development of data doppelgangers can provide real-time visibility into learner proficiency during a course and throughout their career. A data doppelganger (also known as data double, digital twin, digital shadow) is the conversion of human bodies and minds into data flows that can be figuratively reassembled for the purposes of personal reflection and interaction (Ruckenstein, 2014). A data doppelganger extends the typical data collected and integrates more granular interactions from multi-modal sources. These rich data sets are then translated into comprehensive context aware models built from course objectives, Subject Matter Expert (SME) experience, and domain constructs. Furthermore, teaming AI algorithms designed for these types of data sets allows dynamic training recommendations to target specific types of instructional strategies (e.g., desirable difficulties, contrasting cases, stress exposure) and even account for knowledge and skill decay.

For example, actions within a virtual environment can be measured and assessed in tandem with real-time physiological data to compute a dynamic representation of the learner's states, or data doppelganger. With this information, the intensity of a scenario delivered via a stress exposure instructional strategy can either be dialed up or down depending on the performance and physiological state of the learner. In this paper, a conceptual framework for developing data doppelgangers will be presented alongside several possible use cases, recommendations, and considerations.

Creating Geospecific Synthetic Environments using Deep learning and Process Automation

Bodhiswatta Chatterjee, Bhakti Patel, Hermann Brassard
20450

Creation of geo-specific 3D environments for training and simulation require a lot of information along with Electro-Optical (EO) imagery. Acquiring vectors of different object classes along with attributes for each vector is a fairly labor-intensive process. Another important component for making the 3D environment geo-specific is the depth information obtained from Digital Surface Models (DSM) which is expensive, difficult to acquire, and might be noisy. This paper discusses how Deep Learning (DL) based techniques can be used for the extraction of attributed vectors of different object classes from EO imagery and eventually create geo-specific 3D synthetic environments without DSM data.

The contribution of this work is twofold: firstly, multi-level Deep Learning techniques are used for the extraction of building footprints and attributes (e.g., roof type) for each extracted building. Using extracted and derived features (area, shape, etc.), the building heights are estimated which alleviates the requirement of acquiring expensive and difficult to procure DSM data.

Secondly, the problem of creating huge training datasets required to train Deep Learning models is addressed by using synthetic data generated using Presagis software, to solve the problem of roof type classification. A performance-based comparative analysis of classification techniques on synthetic data with other state-of-the-art techniques like few-shot classification is performed to provide insights on how synthetic/hybrid datasets can be used when labeled training datasets are not available.

Finally, a qualitative comparison of two 3D models is performed where the models are created using Velocity (Presagis' workflow automation for the creation of 3D synthetic environments). The two models are created using the same EO imagery and attributes but acquired differently (one manually and the other with AI-extracted attributes), showing that the model with AI-inferred attributes is very close to geo-specific standards, but does not require labor-intensive manual attribution or collection of expensive DSM data.

Generating Simulation Training Scenarios via Event Sequencing

Robert Wray, Joshua Haley, Robert Bridgman
20504

This paper reports a means for transferring behavioral observations captured in operational settings to training simulation. The goal is to enable trainees in a simulation environment to experience training scenarios that mimic observed operational conditions, including specific tactics, techniques and procedures as practiced. The emerging capability generates simulation-training scenarios that replicate events observed in the original setting while also supporting trainee interaction (i.e., not just a scripted replay). The approach is designed to be both simulation agnostic and computationally tractable. Thus, it should be applicable to many simulations and user communities. The paper reports feasibility as implemented within a widely-used DoD distributed simulation environment.

To achieve scenario-generation capability, artificial intelligence and machine learning are used to develop models of the behavioral capabilities of a target simulation and how they can be instantiated and sequenced to produce behaviors, events, and outcomes. Using the inherent capabilities of a simulation itself offers two notable advantages. First, it significantly reduces computational requirements, transforming behavior generation challenges into far simpler recognition problems. Second, it enables interactivity and variation during training by drawing on the underlying simulation's behavioral capabilities. These simplifications make realistic-scale scenario generation tractable.

We describe scenario-generation goals, multiple approaches that we and others have investigated, and results of empirical verification demonstrating a recent approach is functionally sufficient and computationally tractable. In this latest version, captured data is segmented into entity-centric events (e.g., an entity turning "hot" onto an adversary). These event sequences are compared to "behavior signatures" generalized from systematic generation of simulation data. Using algorithms adapted from genetic sequencing, an "event matching" algorithm identifies behavioral signatures that closely align with sequences observed in the original exercise. The resulting simulation scenarios closely reproduce the sequence of events in the original data, but also allow interaction and deviation from the original sequence.

EDUCATION

BEST PAPER

Tactical Combat Casualty Care Training: A Blended Approach for Lifelong Leaning

Matthew Hackett, Joseph Cohn, Carl Schulman
20236

The Fiscal Year 2017 National Defense Authorization Act (NDAA 2017), requiring standardized combat casualty care instruction for all members of the Armed Forces, presented a unique opportunity to address foundational training technology challenges and revolutionize the delivery of medical training. These challenges include: delivering tiered training for distinct levels of expertise, ranging from novice to expert, within a standardized framework; developing a range of training technologies, including apps, manikins, and content authoring tools; integrating disparate training modalities into a common architecture that supports lifelong learning; and leveraging and expanding the science underlying education and training to ensure better learning outcomes. Specifically, this paper will summarize efforts to develop and deliver a joint Tactical Combat Casualty Care (TC3) Training capability, as mandated by NDAA 17 and DODI 1322.24. It will show how this capability, with initial delivery planned for Summer 2020, will transform trauma training

from its current state into a lifelong learning health system that trains and prepares more than 1.5 million military and expeditionary civilian personnel to play a critical role in responding to trauma across the spectrum of military operations. In doing so, this paper will focus on key elements underlying development of this capability including: a longitudinal TCCC curriculum based on learner-centric design; a multi-modality approach to delivering training leveraging learning science including micro-learning and deliberate practice; an emphasis on educating and supporting instructors as well as students; data-driven analytics to demonstrate impact and effectiveness while driving a continual improvement process that is critical to lifelong learning; and a learning architecture supporting these elements that is sufficiently flexible to integrate future scientific and technical advances in education and training.

How PBL abd flipped classroom gave remarkable results in a Military Leadership course at NDUC

Geir Isaksen
20238

Following the new defense educational strategy at the Norwegian Defense University College (NDUC), one of the measures has been to implement Problem Based Learning (PBL), lay the grounds for more student activity and flipped-classroom. Not many papers over the year have looked at the introduction of PBL in higher military education in general or in more specifically in the subject of military leadership. By rebuilding the pedagogical strategies and introduce PBL in the Military leadership (ML) course, the results have been remarkable.

This follows last year's paper about the plans to implement flipped classrooms and PBL across NDUC programs and courses. It gives an overview of how a flipped classroom concept combined with PBL has transformed the military leadership course and discusses the differences between the course conducted in December last year and courses conducted prior to 2019. The shift from a conservative lecture-based course to a more student active and problem-solving approach is highlighted and discussed. Based on pre- and post surveys, grade results and student feedback, both pros and cons are discussed and compared with previous results from the ML courses. The remarkable good results in student performance and other findings are analyzed and compared with exciting research and knowledge within the field of PBL and flipped classrooms.

In conclusion, a summary of all findings and how these will influence the continuing transformation of courses and programs at NDUC is given.

Army Analysis, Modeling and Simulation Education, Training, and Development Effort

Tammie Smiley, Jamie Pilar, Christopher Herrmann, Walter Watford, Laura Harding
20240

The Army Modeling and Simulation School (AMSS) provides targeted education, training, qualification, and certification to ensure the Army M&S workforce, both Functional Area 57 (military) and Career Program 36 (civilian), is well trained in the use and application of the US Army's Analysis, Modeling, and Simulation capabilities. As part of this mission, AMSS routinely updates its education and training opportunities based on the evolving tasks, knowledge, skills, and abilities required. To better understand and address the US Army's current and future analysis, modeling and simulation educational needs, AMSS has been conducting the Analysis, Modeling and Simulation (AM&S) Education, Training, and Development Effort. This paper will describe the AM&S Education, Training, and Development Effort outlining the process used to collect information, analysis of the data collected, and the results of the effort. The process is based on the TRADOC Pamphlet 350-70-14, Training and Education Development in Support of the Institutional Domain, leveraging the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) process. During the years of execution, the process has been refined to best reach all US Army Communities and gather a broad range of interview data from Soldiers and Department of the Army civilians. The data collected is both quantitative and from Soldiers and Department of the Army civilians. The data collected is both quantitative and qualitative and have identified 16 major educational categories, with numerous critical tasks under each major area. Examples of major educational categories include: Data Science, Federating Models and Simulations, Scenario Planning and Development, Data Generation and Management, and Identifying and Applying Existing Army M&S Assets. In response to the findings, AMSS has been identifying existing educational solutions and developing new courses. This effort is an on-going, iterative process and AMSS will continue to seek additional interviews and data on AM&S educational needs across the Army.

Instrumentation Architecture Evolution to Enable Rapid Delivery of Training Solutions

Marwane Bahbaz, Scott Clarke, Rodrick Stubbs
20257

The U.S. Army Project Manager Solider Training (PM ST) office is implementing innovative solutions into its core live training enterprise architecture framework to meet its strategic goal of a well-managed product line that is operationally focused, cost effective, relevant, and current. As part of the PM ST continuous monitoring of its product lines, it became evident that the U.S. Army live training exercise tempo, and the increase in the number of trainees required an evolution to the Common Training Instrumentation Architecture (CTIA). As a result, PM ST realigned its modernization roadmap to address the new requirements. CTIA enhanced its Service Oriented Architecture to account for new design elements, using micro services, orchestrated containers for virtualization, coding abstraction from configuration data, continuous integration, and continuous delivery concepts. These enhancements enable PM ST to deploy functionality in small, manageable chunks at a rapid pace, and permits the use of horizontal scalability to match the live exercise's capacity at the point of need. In order to meet these design elements, PM ST integrated several key Department of Defense (DoD) approved technologies, processes and enablers. These innovative technologies and design elements not only meet the urgent need of the current live training environment and achieve PM ST strategic goals, but also lay the framework for the live training transition into the Synthetic Training Environment. The growing needs of training enablers are present in other DoD environments as indicated by direction in the DoD Enterprise DevSecOps Initiative, and the newly released memorandum "Software Acquisition Pathway Interim Policy and Procedures" by the Under Secretary of Defense. This paper will thoroughly discuss the background, design elements, and the selected technologies, as well as how they will improve the deliveries of new training capabilities, in quality and frequencies, to the warfighter to meet PM ST strategic goals.

The Making of a NCO: From Team Member to Team Leader

Holly Baxter, Larry Golba
20288

Noncommissioned officers (NCO) are the backbone of the U.S. Army, and building the next generation of NCO leaders is always an essential component of meeting current and future mission requirements. Recent research has indicated that the transition from junior enlisted Soldier to NCO is often daunting as Soldiers face challenges in professional, personal, and social domains due to the change in status from follower to leader. Therefore, the purpose of this research was to identify challenges and barriers to a successful transition and to identify successful strategies employed to navigate the transition. We conducted focus groups and interviews with approximately150 NCOs to capture their personal experiences leading up the transition, as they were in the midst of the transition, and, retrospectively, after establishing themselves as a leader. We also administered questionnaires to approximately 150 NCOs to quantify experiences in this transition phase. Results suggest that many prospective and junior NCOs struggle with confidence, motivation to lead, and basic leadership skills. However, the results indicate that junior enlisted leaders report that they generally acquire the necessary skills and self-development aspects as they perform required duties as a leader. Together, the results suggest that earlier exposure to these activities may accelerate and ease the transition process for many NCOs.

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Exploring the Characteristics of Immersive Technologies for Teamwork

Beata-Noemi Balint, Helen Dudfield, Brett Stevens, Wendy Powell
20293

Teams are essential components of Defence Organisations where teamwork errors, whilst rare, can lead to fatal consequences (Baker, Day, & Salas, 2006). Due to the increased costs and risks of live training, these organisations are increasingly employing synthetic team training solutions. These are advocated as effective media for the training of teamwork (Delise, Allen Gorman, Brooks, Rentsch, & Steele-Johnson, 2010), with a growing interest in the adoption of immersive Virtual Reality (VR) systems. However, these technologies come with an increased cost of content development (Bogan, Bybee, & Bahlis, 2019) and are generally met by a resistance to change. Although, there is anecdotal evidence of a training benefit of immersive technologies, there is an opportunity to explore whether their innate features support teamwork. Therefore, in order to justify the procurement of immersive team training systems, there is a need for empirical research to ascertain the optimal technology architecture for training teamwork. In this paper we describe early results to empirically explore the support offered by technological immersion, presence, and psychological fidelity for teamwork. Specifically, we looked to

examine the relationship between these constructs and their effect on participants' perceived ability to engage in teamworking behaviors. Participants were divided into 6 teams of 4 and were asked to play a co-operative COTS video game (PayDay 2) with either a desktop set-up (low immersion) or an HMD set-up (high immersion). The results suggest that participants in the HMD condition reported lower teamwork, lower presence, lower usability, and higher workload, when compared to the ones in the Desktop condition. We conclude that participants' lack of familiarity with the VR system may have represented an additional source of extraneous cognitive load, impeding them from engaging in teamwork as well as the participants in the Desktop condition. Lessons learned and implications for practice are discussed.

Create and Host Cyber Competition Using the Preliminary Persistent Cyber Training Environment (PCTE)

Cliff Zou, Christopher Thompson, Gabriel Bearden, Ty Sloan, Roy Laurens, Bruce Caulkins

20306

As the world becomes more interconnected and our lives increasingly depend on the cyber world, the increasing threat of cyberattacks and cybercrimes make it critical for us to provide better and practical training of the cybersecurity workforce. In recent years, cybersecurity competition has become one of the most effective and attractive way for educating and training college students or professionals. In this paper, we first systematically introduce in details the step-by-step procedure and technical knowledge on how we take use of the ongoing DoD cyber-range environment called Persistent Cyber Training Environment (PCTE) to set up cyber competition virtualization environment, configure and install operating systems and popular services with various well-representative vulnerabilities, and set up the participant's access and scoring system. Then we introduce the cybersecurity competition successfully organized by us in I/ITSEC 2019 conference, and the experience and lessons learned from this real-world competition event. The technical details and knowledge presented in this paper could help other researchers and educators to set up their own cyber competition environment or event to better train the future cybersecurity workforce.

Exploring the Benefits of Adaptive Learning Methods

Krista Ratwani, Evan Oster, Alan Carlin

20326

Every branch of the military has called for the need to embrace personalized, adaptive learning methods tailored to each learner's unique profile of strengths and weaknesses (Department of the Army, 2011; Roberson & Stafford, 2017; U.S. Fleet Forces Command, 2017). While the effectiveness of adaptive learning is well-established (VanLehn, 2011), there may be boundary conditions under which adaptive learning methods are most effective. Therefore, the purpose of this study was to examine such conditions. Participants (N = 76) recruited from Amazon Mechanical Turk engaged in a mathematical task to train and assess their skills in order of operations. A pre-test administered to all participants was used to classify each participant at a beginner, intermediate or advanced level. The pre-test was followed by multiple problem sets of varying difficulty levels, and then a post-test. To progress through the problem sets, participants were randomly assigned to a control learning condition (n = 49) or an adaptive learning condition (n = 27). For the former, participants progressed linearly through a set of math problems. For those participants in the adaptive learning condition, the difficulty of each problem set was determined based on their prior performance. The criterion measure of learning was operationalized as the gain between the participants' pre-test and the post-test scores. The results revealed no main effect of instructional condition (adaptive versus control). However, moderator analyses demonstrate the presence of an interaction between instructional condition and prior knowledge. Specifically, the greatest learning gains were observed for beginners in the adaptive learning condition. Smaller gains were also observed by advanced learners in the adaptive learning condition. By comparison, intermediate performers learned most in the control condition. These results suggest that for "average" learners, the traditional, linear path to learning may be sufficient. Lessons learned and implications for future research are discussed.

A Future Vision for the Defence Learning Ecosystem

Megan Pleva, Abby Laishley

20347

The UK Ministry of Defence (MoD) recognizes that operational doctrine is changing in response to the emerging realities of international and domestic Defence requirements. This has profound consequences for any learning system. The MoD is also discovering that the benefits posed from delivering new learning themes, that focus on the optimisation of human factors, are difficult to quantify using traditional metrics. The challenge is to deliver the most cost-effective and human-centered approaches to what can often be a diverse and changing set of requirements.

This research initially explored relevant education and training literature. Eight interviews and a stakeholder workshop were conducted with key training and learning specialists and current students in UK Front Line Commands (FLCs) (Joint/MoD Head Office, Royal Air Force (RAF), Royal Navy (RN), and the British Army) to analyse the current Defence Learning Ecosystem and understand change requirements. Findings indicated that learning analysis, design and assurance must become more agile and braver in future, to deliver maximum impact and increased value. The following key themes were raised: data, scope, barriers, optimisation, and motivation.

Research showed that the hierarchical nature of the current Defence organisation acts as a blocker to innovative instructional approaches within the current Learning Ecosystem. Changes are needed to improve the current Defence Learning Ecosystem into a coherent and adaptable process. Recommendations for UK Defence highlight focus on 'Primary Concept Realignments' which outline a dynamic and intuitive interaction between seven core anchors (people, culture, strategy, content, technology, governance and communication). Following implications include benefits for learning strategy development and governance in UK MoD future training. This will be developed further to describe a phased roadmap for optimising resources and managing change, framed around the core anchors and their connective tissue.

Human-Machine Teaming: What Skills do the Humans Need?

Samantha Dubrow, Kara Orvis

20371

Over the last few decades, technology has become increasingly intelligent. Technology is no longer a passive tool that supports a single human in their work, but an active teammate that collaborates and learns as a critical entity of the team. To date, human-machine (HM) teaming research has primarily focused on the machines – how to design them, what their capabilities are, and how they can "learn." This conceptual paper takes the opposite view, focusing on the importance of selecting and training humans to be effective HM teammates. To that end, this paper will address two questions: What unique skills do humans need to work well with machines as teammates, and how are those skills different from those required for effective human-human interactions? The challenges that HM teams face drive the identification of the human skills. For example, humans are fundamentally biased to anthropomorphize machines and expect them to act like other humans (Proudfoot, 2011). Consequently, humans expect to understand and predict how and why machines are making their decisions. When machines do not act in accordance with human expectations, trust and coordination between humans and machines quickly break down (Mueller, Hoffman, Clancey, Emrey, & Klein, 2019). To mitigate this effect, we build machines with explainable AI to provide humans with insight into their decision making (Mueller et al., 2019). We can also improve HM teaming by selecting humans who have individual traits such as openness to new experiences, tolerance for ambiguity, and high propensity to trust. Humans can be trained on perspective taking skills to understand how machines make decisions (Galinsky, Ku, & Wang, 2005). In addition, identifying the skills humans need to work with machines, this paper will make suggestions for how to train humans and machines together for effective HM team performance (Nikolaidis & Shah, 2013).

Applying Instructional Design Fundamentals to Next Generation Training Development

Catherine Thistle, Jason Noren, Beth Mead

20414

Instructional designers are not simply adapting to a single evolutionary development in the training continuum; they are operating at the nexus of a new generation of super technology users and a rapidly expanding landscape of learning theories, development platforms, and technical capabilities. These super users are warfighters who have unprecedented access to eLearning, presented in high-definition across familiar platforms, with just-in-time access to fast-track tutorials at their fingertips. At its core, immersive reality learning is a contemporary extension of eLearning, and while the shiny-object allure is attractive to both the warfighting learner and supporting organizations, there is a body of instructional design knowledge and research used successfully for decades and still translates effectively to today's eLearning platforms. Even with cutting-edge extensions of eLearning such as immersive reality learning and performance support being fully realized today, technologists need not dismiss perceptively antiquated, but time-tested and effective approaches to adult learning and instructional design; the wisdom of the past can - and should - help to inform our developments of the present. This paper aims to explore the application of traditional instructional design approaches to meet the needs of today's learner given emergent technologies in the new learning paradigm.

In the new learning paradigm, instructional designers continue longstanding implementation of core principles in andragogy and training development for

next generation learners accessing next generation learning platforms. Front-end analyses remain critical at the outset of training development, ADDIE and SAM models continue to have value in the production pipeline as industry standard waterfall and Agile iterative methodologies, and Kirkpatrick's levels of evaluation can still be used to measure participant learning and organizational change post implementation. This paper expounds the application of traditional instructional design approaches to meet the needs of today's learner given emergent technologies in the new learning paradigm.

Factors Impacting Virtual or Augmented Reality Effectiveness in Training and Education

Jeffrey Liang
20416

Numerous advances in virtual and augmented reality (VR/AR) technologies have made them far more accessible and affordable than ever before, and as devices proliferate there are wide variations in approaches to realism, immersiveness, interactivity, and emotional connection to the user. With so many options to choose from, it is important to examine whether these technologies and techniques have a measurable impact on learning outcomes when compared to traditional methods. This paper examines specific elements of VR/AR to help quantify their impact on learning outcomes and whether their effectiveness changes based on different military applications such as combat simulations, emergency medical training, classroom instruction, and leadership development. The result is a framework that should assist decision makers maximize their return on investment during curriculum development by illustrating which features would be worth the investment for different training scenarios.

Effective Data Management Strategies for Training and Readiness

Ahmed Humayun, Bryant Choung
20420

In order to ensure that our Warfighters are appropriately trained for the next fight, an effective data management strategy built around identifying, integrating, analyzing, and understanding relevant data is critical to success. There is a growing collection of real time and historical information that is relevant to understand how we're training to fight, including data generated during training events, empirical data that helps inform and structure training scenarios, data pertaining to individual soldiers, data from training equipment and systems that track soldiers, and many others.

Our proposed study will incorporate experience from a variety of Government and commercial customer spaces in how advances in commercial industry around data management technology can be leveraged, including efficient data fusion, Artificial Intelligence (AI) and Machine Learning (ML) strategies to detect and identify patterns, and algorithmic approaches to optimize the prediction of future performance. Our study will also explore common challenges in utilizing such tools in developing appropriate data management strategies, including:

- Integrating data of different types and formats from a variety of disparate sources
- Applying novel AI/ML, and algorithmic techniques to data analysis and the execution of operational workflows
- Providing accessible tools and user interfaces that allow non-technical users to benefit from advanced analytics
- Enabling collaboration across security, organizational, and even national boundaries

The results of these case studies, to be presented in our paper, will provide courses of action for implementing data management technology. Such capabilities will enable stakeholders from across the training enterprise – from senior decision makers to individual soldiers – to better evaluate unit and soldier readiness and the effectiveness of ongoing training.

Analytic Evaluation Strategies for Training Systems

Regan Patrick
20430

"Big data" sources are enabling training system designers to leverage analytics to create individualized learning approaches better aligned to student needs. As our ability to collect and understand performance data improves, the need to reexamine legacy training evaluation strategies and systems has grown as well. Analytics has improved our understanding of how students achieve competency and provided insight into system-wide changes that are required to sustain or improve individual and program achievement. The challenge for instructional designers is how to "design-in" feedback mechanisms for decision-making processes. Feedback data can determine not only the effectiveness of student accomplishment, but also the efficiency of all enterprise processes aligned with evolving expectations of the gaining unit. Instructional designers need to know how to access performance data to validate current training system design and shape future training system constructs. We know technology generates data, but what data should feed advanced AI algorithms to support training and resource decisions at the local and enterprise levels? How can emerging training and learning technologies integrate with analytic strategies to identify Training Return on Investment (T-ROI) and future value propositions? How can training managers know they are meeting both student and end user requirements?

This paper explores how to develop and deploy evaluation strategies that provide meaningful input to training system design in complex programs. It provides approaches to help instructional designers, training managers, and instructors leverage feedback to shape long term learning behaviors, refine syllabus requirements, and improve overall system performance aligned with end user expectations. The paper recommends effective ways to examine data on how students achieve their learning objectives, and describes a framework to help training managers know what should be measured and how much, from whom and how often - questions fundamental for training system optimization today and into tomorrow.

Transfer learning to create and understand modular content

Joshua Haley, Jeremiah Folsom-Kovarik, Alejandro Carbonara
20441

Machine Learning (ML) has offered innovative benefits in automated content analysis and discovery. In the commercial space, sophisticated Deep Learning (DL) neural models have enabled systems capable of better understanding queries and the content being searched. More recently, an AI system was able to comb through a large dataset of scientist literature to discover a new novel antibiotic. While it might seem that understanding our content is a solved problem, these breakthroughs have come at the cost of the large amount of data required for training the neural networks so that they correctly process technical terms and specialized language use. It is often the case for Military applications, that the amount of data available is far more limited. The question becomes: How can we leverage recent advances with sparse data to train the warfighter?

This paper presents a system utilizing the key advances in textual Deep Neural Embeddings by leveraging transfer learning from a larger corpus in order to automatically understand content topics. This automation of understanding allows for enhanced automated meta-data to be annotated with fine granularity without increased book keeping for content developers. This understanding allows for content to be automatically indexed, annotated and modularized, aiding in training content reuse and adaptation without additional task load on instructional content designers. Individual varied instruction is envisioned in the Department of Defense's future warfighter training systems. Creating and using fine-grained meta-data for instructional content is a necessary enhancement to support individual varied instruction because it helps to answer how content can be modularized, what learners can be expected to know after using the content, and which content should be presented to optimally teach and train learners in different contexts, backgrounds, and performance.

Certified Modeling and Simulation Professional 3.0 – Reinvention!

Ivar Oswalt, Sean Osmond, Mikel Petty, Eric Weisel, Linda Brent, Steven Gordon, Alan Lynch, Gregory Reed, George Stone, Fuzzy Wells, Neal Finkelstein
20446

Career certification plays a key role in establishing the legitimacy of any occupational field. For modeling and simulation (M&S), this recognition is earned primarily through becoming a Certified Modeling and Simulation Professional (CMSP). Achieving CMSP certification means that an individual has the education, experience, professional standing, ethics, and knowledge required of a true M&S professional. Yet, CMSP processes and criteria need to evolve with the times. Adjacent technologies are emerging, like artificial intelligence and machine learning, that drive change in M&S; applications are envisioned in new domains like space warfare and multi-domain operations; and a new breed of tech-savvy and process weary inductees is joining the M&S ranks. Being a CMSP demonstrates knowledge and currency in a constantly changing career field that goes beyond proficiency demonstrated by academic degrees, experience, or government or corporate affiliation. There is a constant need to educate, inform, and reach out; any certification program needs to be regularly revisited to remain relevant. An M&S community-led update of the CMSP program, now nearing completion, identified key initiatives and ongoing activities to increase the demand signal, improve awareness, restructure the certification process, coexist with other M&S and related certificates, increase certificate holder engagement, consider new certifications and sub-certifications, revise and update the exam, and develop and implement a marketing plan. This article describes where the review and update processes stand today and provides a roadmap to an

exciting and renewed CMSP program that will benefit the next generation of M&S professionals.

The Makings of Effective Research!

M. Beth Pettitt
20467

The pace of technological change requires an agile research and development process where high level requirements are quickly, almost instantaneously defined, refined and articulated. Contrary to the view of the solitary mad scientists in the secret back room, effective and timely research requires a robust team, stable funding, innovative scientists, disciplined processes, a user community identifying the technology gaps, and of course visionaries to describe what the future might look like. This paper will leverage the experiences from over twenty years of Department of Defense research to describe the attributes of successful research, testing and transition. The DoD's seven budget categories of research and development (6.1 to 6.7) as well as the nine Technology Readiness Levels will be explored and discussed as they relate to the progression of projects moving from basic research to successful transitions. Several successful examples from the medical modeling and simulation community will be cited and discussed in detail.

Additionally, methods to describe and evaluate proposed research programs, such as the often used ""Heilmeier Catechism"" eight questions will be discussed. Appropriate testing for different technology readiness levels will be explored including from simple usability assessments to Training Effective Evaluations and how these compare to operational testing. A few pitfalls of unsuccessful research efforts will also be described, citing specific examples. Finally, a timeline will be presented for beginning a successful research project, including funding and transition strategies.

Development of an Agile Workforce, Agilely: A Case Study

Anne Little
20499

A 2018 Harvard Business Report which surveyed nearly 1,300 IT and business leaders indicated approximately four-fifths of respondents are "using Agile in some form" to accomplish principal business functions, and three-quarters are "embracing agile ways" (Panditi, 2018). However, ensuring Agile is implemented consistently is another matter. These same respondents, self-reported their implementation consistency was less than 20%. Within DoD, the ability to develop software rapidly is critical because "cyber warfare … has become at least as important as physical fighting" (Denning, 2019). The impact of the disparity in operations between teams who use Agile and those who do not pose technical risk to organizations which do not bridge the operational divide.

In early 2020, the author led the rapid development of an integrated knowledge management system with software engineers using DevOp and Agile practices. The subject matter experts who would use the system did not have Agile experience, but their engagement with the development team was vital to the success of the end product.

One method to improve our skills within the workplace is transfer. Tishman, et al., (1995) define transfer as occurring whenever we "carry over knowledge skills, strategies or disposition from one context to another." For members of the workforce who have become highly skilled operating a hierarchical or waterfall environments, this creates a big problem. So few of the Agile and non-Agile practices map to each other very well. Not only are previously successful skills no longer useful, the method by which we have learned in the past won't help as one tries to become proficient in an Agile environment.

This paper presents the methods by which the author used an Agile development project as a vehicle for non-Agile practitioners to develop an Agile mindset. Ways to scale this technique within the broader workforce are also provided.

HUMAN PERFORMANCE ANALYSIS AND ENGINEERING (HPAE)

BEST PAPER

Towards the Development of an Automated, Real-Time, Objective Measure of Situation Awareness for Pilots

Sandro Scielzo, Justin Wilson, Eric Larson
20502

Measuring mission-critical, higher-order cognitive constructs automatically is a priority within the DoD to achieve third-offset goals, accelerate training of complex skills, and support multi-domain warfare. Situation Awareness (SA) is one such construct, but its measurement is burdensome, relies on post-hoc analyses, and provides little immediate value in training or operational environments. Wilson and colleagues (2020) demonstrated that targeted application of Machine Learning (ML) on biometric data can yield real-time, accurate performance classifiers evaluating pilot eye scan techniques and mental workload. The current study established the relationship between the three levels of SA (i.e., perception, comprehension, and projection) and corresponding proxy ML classifiers, such as eye scan accuracy and mental workload, to lay the foundation for a real-time SA index that is diagnostic of performance. Forty participants, including pilots with varying levels of expertise and an ab initio control group, participated in a meticulously controlled, within-subjects experiment that involved flying an intercept mission using an F/A-18 mixed-reality trainer. Situation awareness was measured using the Situation Awareness Global Assessment Tool (SAGAT), and we used the NASA Task Load Index (NASA-TLX) to gauge mental workload – both subjective metrics are industry gold standards. Eye scan accuracy and mission performance were graded by experienced instructor pilots. Statistical analyses describe the relationship between level of expertise, eye scan accuracy, mental workload, and performance across SA levels. This experiment is unique as it presents results that provide a foundation for a real time, objective, and accurate SA index. Study findings highlight expected benefits for both training complex skills and high-stakes dynamic operational environments.

Machine Learning as an Effective New Tool for Assessing Human Performance During Simulation-based Training

Roger Smith, Danielle Julian
20207

This project explored the potential for using machine learning (ML) models to analyze and score videos of simulation-based surgical training. The experiment broke the problem into three phases: (1) identifying objects in the video, (2) classifying the dynamic activity being performed, and (3) assigning a score to the quality of performance demonstrated. Our 2019 I/ITSEC paper reported the results of Phase 1. This paper addresses Phases 2 and 3.

1,735 videos containing five unique activities to be classified were processed with Goggle Cloud Platform tools - assigning 1,235 videos to the training set, 250 to test, and 250 to validation. Google AutoML was trained to classify the activity in the videos. The same steps were applied to predicting performance scores. Models can be created with this small data set only because AutoML leverages transfer learning and network architecture search techniques.

An AutoML generated model was able to classify the activities in the videos with an accuracy of 88%. The same process created a model that was only 65% accurate when predicting the performance scores. The activity classifications approach levels for satisfactory automated classifiers. The performance scoring model accuracy was too low to replace human evaluators. Low accuracy on performance scoring was expected since the data set was divided by both activity and quality level, resulting in fewer instances in each group. Using the same data set, ML techniques that can classify activity would necessarily be less accurate at recognizing good vs. poor performance of that activity. Achieving higher accuracy in scoring will require significantly larger data sets. Additionally, the subtlety of Phase 3 may call for entirely different ML techniques than those successful for Phases 1 and 2. The ML literature indicates that effective techniques for automated performance scoring is a topic of interest to multiple research teams.

Performance Assessment Using Individual Skills Linked to Mission Outcomes

Brad Gilroy, Dave Harris
20211

Traditional performance assessment techniques utilize a top-down approach focused on mission outcomes (i.e., "what" occurred). Unfortunately, these techniques often fail to uncover "why" the outcomes occurred, which is critical information for training and resourcing decision makers. An alternative approach that focuses on the factors that directly affect mission outcomes (i.e., individual skill execution coupled with systems reliability), has traditionally been deemed "impossible" due to the fidelity of data required. However, in 2015, a team of former TOPGUN instructors in support of NAVAIR and CNAF, overcame significant challenges (e.g., disparate data sources, historically subjective/self-reported assessments, etc.) to develop and apply a methodology that links the performance demonstrated by F/A-18 aircrew at the TTP level of execution to team/mission outcomes during live training events. Over the last five years, this new approach to data collection and analysis has been developed into an automated toolset and applied to hundreds of F/A-18 training events. The results provide unprecedented insight

into the individual skill and aircraft systems deficiencies that have the greatest impact on F/A-18 mission outcomes. The data collected during these exercises also enables the application of groundbreaking AI/ML data analytics to derive standards for individual performance that directly link to desired combat outcomes. In addition to providing invaluable feedback to the F/A-18 aircrew, CNAF is currently relying on this effort to inform decisions ranging from syllabi improvements to resourcing investments, which proves the utility of this new approach. Although initially demonstrated in the context of live F/A-18 air warfare, the process has now been demonstrated across multiple platforms (e.g., E-2C/D, EA-18G, etc.), mission sets (e.g., STW, C2, AEA, etc.), and training environments (i.e., live, virtual/constructive, and LVC), and is scalable to other disciplines. This skills-based approach to performance assessment, once deemed impossible to achieve, represents the future of automated performance assessment.

This is my robot. There are many like it, but this one is mine.

Daniel Yurkovich, Glenn Hodges, Christian Fitzpatrick, Mollie McGuire
20217

The USMC is committed to putting time and capital into developing autonomous systems that will aid its Marines. However, autonomous systems are only useful when they are used, and a large determinant of use is trust. In many cases, systems go unused due to the human's skepticism regarding its trustworthiness. As machines transition from tele-operated towards partially or fully autonomous; the capabilities, limitations, and reasoning behaviors of the machines will further mystify users and inhibit trust. Experience and continued use with automation can facilitate the development of trust, but the complexities, maintenance, and cost of future machines create an environment that is prohibitive to daily real-world training with autonomous systems. These two factors, (a) an inability to understand artificial intelligence (AI) and (b) an inability to train daily, contribute to an atmosphere of mistrust in valuable systems – systems designed to aid the warfighter in mission success. The current research explores how to develop trust in autonomous systems while not being able to regularly train with them. The aim is to research how trust is developed and transferred from a virtual environment to live execution. Autonomy will consist of AI agents perceived to be created by either automatic or interactive Machine Learning (ML) techniques. It is predicted that a virtual gaming environment that enables interactive ML (iML) of the autonomous system will facilitate the development of trust in the system for live execution. This paper will include objective and subjective data from field experiments conducted with Infantry Marines at Camp Lejeune, NC; and will focus on applicable gaming environments for iML to facilitate the development of trust in autonomous systems. This research directly supports the Commandant's vision and US Army desires to increase the use of unmanned lethal and non-lethal systems in operations.

Intellection: A Game for Intelligence Collection Planning and Group Decision-Making Optimization

Mary Frame, Justin Morgan, Monique Brisson, Holly Zelnio
20276

We have developed a collaborative team board game, Intellection, which provides group decision making and path planning instruction in a more engaging manner than traditional lecture-based methods. This game furthermore has been effectively leveraged as a research tool to understand the cognitive processes that underlie path planning and adaptive sequential decisions. Our applied motivation derives from intelligence gathering operations that require signals, images, full motion video, and ground radar information to be gleaned from particular areas of interest using a variety of platforms and sensors. Individuals who manage these collections operations must plan initial collection paths, and must further adapt those paths based on emerging requirements, additional opportunities to collect important information, and disasters that could compromise data collection. However, there are typically more targets of interest than there are resources to collect them, demanding individuals to assess the tradeoffs of taking a particular course of action over another. Furthermore, different individuals on a team may be responsible for different types of collection, all of which must be cross-coordinated. Teaching this skillset can be difficult, particularly when team members are geographically separated and team communication is limited and distributed. Intellection provides an engaging tool for developing these critical skills for in-person teams. For distributed teams, we are developing a software version to provide a common visual interface for these teams to work on these skills. We present the initial research, development, refinement, and deployment of Intellection, as well as the results of our initial pilot work tested on multiple groups of novice and expert collections analysts. The framework developed for the Intellection game can be further customized to collect information on individual and group cognition within a variety of Department of Defense pertinent problems spaces. It also serves effectively as a research tool for optimizing operations and group decision-making processes.

Teamwork and Lethality in a Support by Fire Team

Gregory Goodwin, Katlin Anglin, Jacquelyn Schreck, Grace Teo
20309

To support broader Army efforts to operationally define squad lethality, our team conducted foundational research to identify team performance measures in Army fire teams engaged in a support by fire task. Based on a review of existing literature and field training observations, we identified critical measures of teamwork and weapon engagement. These measures were collected from eighteen squads that executed battle drill 2A (squad attack) once during the day and once at night using live fire. Squad communication measures, including information exchange, leadership, communication quality, and implicit coordination, were captured using audio recording devices placed on each member of the support-by-fire team. Lethality measures included probabilities of hits and kills, target suppression, changes in firing rate and distribution of shots around each target using location of miss and hit (LOMAH) sensors. This paper examines the role of team interactions including the type and timing of information shared, leadership and coordination on lethality measures. The impact of demographic measures like time in service and record fire score are also accounted for. These findings are being used to identify squad level measures of teamwork that are critical determinants of squad lethality for use in a squad performance model.

Assessment of Confidence Impact on Training Performance

Gianna Avdic McIntire, Amy Dideriksen, Thomas Schnell, Katharine Woodruff, Colton Thompson, Jessica Greenwald
20358

One of the best predictors of student performance is an individual's belief or confidence that s/he possesses the necessary abilities and skills to complete a task within a context. Confidence is a key psychological variable and most frequently conceptualized as self-efficacy. A new construct related to confidence is core-confidence, conceptualized as a higher-order core construct that influences four manifestations, including hope, optimism, self-efficacy, and resilience (Stajkovic, 2006). Confidence is a key determinant to whether one will unleash existing potential, or hold it internally captive (Stajkovic, 2006). A confident individual is one who knows what to do, how to do it, holds positive future outcome expectations, and can bounce back from suboptimal outcomes.

Despite the vast body of research suggesting that one's confidence belief is the single best predictor of human performance, there is little evidence of its implementation in real world training environments. To optimize training performance, training systems designs must incorporate an understanding of the changes in one's confidence beliefs and how those beliefs affect performance outcomes. In this study, we utilize subjective measures of state-based core-confidence, and objective measures of Training Effectiveness (TE), which is measured through a combination of task-performance and physiological data. The main research question we seek to answer is whether simulated training environments contribute to a false overconfidence that transfers into live environments, ultimately affecting performance outcomes. To understand the role of state-based core-confidence in training effectiveness framework, we associate it with our TE measures to determine how it changes through the training, how it varies between simulated and live flight environments, and how its changes affect subsequent performance in both environments.

Our study assesses state-based core-confidence to validate if it can be used as a deterministic variable for designing the fidelity of simulation-based training devices.

Warfighter Physiological Status Prediction

Zhiqing Cheng, Gary Zientara, Reed Hoyt, Diana Sanford
20364

Dismounted warfighters often experience physiological strain close to their physiological limits in their missions, such as patrolling in a desert in high temperatures or venturing through high mountain terrain with a restricted oxygen supply. The physiological strain experienced by a warfighter not only affects his/her performance but may lead to injury or even death. Therefore, in this paper, investigations were performed to develop a systematic procedure for predicting an individual warfighter's physiological status, that includes (a) Environment set-up, to identify geolocation and to determine the environmental conditions for a mission; (b) Warfighter modeling and simulation, to create a digital human model for an individual warfighter and to replicate his/her mission activities by animating the model using motion capture data; (c) Physical activity energy expenditure analysis, to calculate the metabolic energy required for a warfighter to undertake his mission tasks based on the inverse kinematics of his/her body motion; and (d) Physiological status prediction: to predict the status for an individual warfighter based on his personal physical/physiological characteristics, environmental conditions, and activity intensity represented by the rate of metabolic energy required. An initial software system was developed to implement the procedure and to provide

basic capabilities for the prediction. Case studies were performed to test and demonstrate the functions of the software system.

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AR Psychological Suitability: Training Receptivity and Training System Efficacy

Peyton Bailey, Claire Hughes, Jennifer Riley, Kay Stanney, Cali Fidopiastis, Samuel Haddad

20367

Augmented Reality (AR), in which computer graphics and relevant data are superimposed onto a user's natural world view, affords the potential to provide contextually rich and immersive training solutions that can substantially enhance learning (Lee, 2012). Additionally, leveraging AR presents the possibility to create/deploy/practice training more rapidly, while alleviating monetary and human resources. However, little is known about the short and long-term effects of AR usage on human cognitive-affective training performance (e.g., stress, engagement, etc.) or how these factors interact and affect knowledge acquisition, retention, and transfer. AR and virtual reality (VR) research suggests significant impact of individual differences (such as spatial aptitude, immersive tendencies, and user self-efficacy) on one's ability to learn in immersive environments (Chen & Wang, 2015; Riley et al., 2004; Witmer et al., 1996), but these impacts in AR are not well characterized. Beyond individual differences, research indicates that task factors such as type (psychomotor, cognitive) (Schmidt-Daly et al., 2016), duration (Kennedy et al., 2000), complexity (Khademi et al., 2013), and skill requirement (Condino et al., 2019) influence AR training outcomes. However, these factors have not been systematically evaluated to define how they impact user psychological constructs during the learning process. This research aims to identify and quantify the degree to which differing types/natures of tasks, and their presentation in AR environments, effectively promote skill development and training transfer. By evaluating both cognitive and psychomotor task performance during and after AR training, using varying levels of virtual/physical interactions and cues, it will be possible to determine the effects of task receptivity on training performance. Results from this assessment will inform development of AR usage and design guidelines, usability criteria, best practices, and recommendations that will help ensure that the tasks, and their instantiation within the AR space, best support efficacious use in military and civilian training.

Cognitive Expertise through Repetition Enhanced Simulation (CERES): Training to Understand Topographic Maps

Paul Reber, Evan Grandoit, Kevin schmidt, Marcia Grabowecky

20378

Understanding a topographic map is a non-trivial perceptual andcognitive process that is a critical part of Land Navigation training. Here we describe progress with an accelerated training protocol using high-repetition simulation-based training to develop map reading skill prior to field exercises. This novel training approach, CERES, is based on procedurally-generated microsimulations that provide practice repetitions connecting a topographic map to a first-person terrain viewpoint. Each simulation-based training event is completed in 30-60 seconds, allowing for large numbers of training microsimulations to be completed per hour of study. This high-repetition approach triggers the process of implicit learning, leading to the development of fluid, automatic, and expert cognitive performance. The CERES training approach is accomplished using procedural generation of terrain environments, associated topographic maps and first-person perspective videos of movement through the terrain. Participants indicate understanding of the map by reporting the orientation of video movement on the matching topographic map. Feedback about the accuracy of this orientation judgment is provided and task difficulty is adjusted adaptively to guide learning. With practice, participants gradually improve their ability to connect the three-dimensional terrain video features of the simulated environment with the structure implied by the contour lines from thetwo-dimensional topographic map representations. Understanding the relationship of map to environment is necessary for navigation and to makeplanning decisions appropriate to the environment. The CERES training approach is designed to supplement traditional classroom instruction and support initial steps toward expertise through simulation-based practice prior to experience in the field.

Performance assessment in a virtual simulation for integrated austere medical operations training

Benjamin Bauchwitz, Michael Makivic, William Manning, James Niehaus, John Broach, Peter Lancette, Christopher Garrison, Frank Ritter, Peter Weyhrauch

20388

The DoD is preparing for future austere environments where it will not be possible to sustain the current level of medical operations across the chain of care. Enemy activity, resource depletion, and lack of safe spaces to deliver care will all provide unique challenges to the performance of medical operations. Under these circumstances, medical operations will require the coordination of personnel outside traditional medical roles, such as those involved in logistics or mission command. The DoD has neither a curriculum nor a suitable training system for teaching the skills necessary to succeed in these operational environments.

Here we report initial work designing the training curriculum and performance assessment metrics for Extensible Field and Evacuation Care Training in a Virtual Environment (EFECTIVE), a virtual simulation for training, practicing, and assessing the skills for managing medical operations in austere and far forward environments. EFECTIVE is intended to provide training for personnel in traditional medical roles (combat lifesavers, flight nurses, field surgeons, etc.) as well as those in roles that interface with medical personnel during complex missions. This training is designed to emphasize coordination of activities across these different roles as well as the problem solving and decision-making skills that become necessary when medical operation cannot be performed as intended.

We applied the Methodology for Annotated Skill Trees (MAST), a previously published cognitive task analysis framework, to design the curriculum for this training system. The results of this initial work were (1) a set of plausible training scenarios inspired by challenges faced by today's Warfighters but expanded to represent future austere battlespaces; (2) a set of critical skills needed by medical, logistics, and mission command personnel to successfully perform their duties in these scenarios; and (3) definitions for concrete, objective metrics for assessing proficiency on these skills in the EFECTIVE simulation environment.

Surgical Training Effectiveness Using Immersive Virtual Reality

Ryan Lohre, Danny Goel, Aaron Bois, George Athwal, J Pollock, Peter Lapner

20429

Background: Contemporary immersive virtual reality (iVR) simulators have shown validity in surgical training. Measures of training effectiveness compared to traditional training modalities as pioneered in aviation and military training must be determined.

Hypothesis: Can iVR improve learning effectiveness compared to traditional media teaching measured through transfer of training (ToT) and transfer effectiveness ratio (TER)?

Methods: Eighteen orthopaedic surgery residents (PGY4-5) from multiple institutions were recruited for a randomized, intervention-control study. Randomized residents received iVR training (experimental group; n=9) on reverse total shoulder arthroplasty (RTSA) with augmented baseplate for rotator cuff tear arthropathy, or technical instructional video training (control group; n=9). Residents completed baseline demographic questionnaires, followed by a written knowledge test after training sessions. Residents were individually evaluated by blinded expert shoulder surgeons on performing a RTSA on fresh-frozen cadavers using Objective Structured Assessment of Technical Skills (OSATS) and Global Ratings Scale (GRS) metrics.

Results: Participant experience with RTSA (p=0.73), simulator (p=1.0), or VR (p=1.0) did not significantly differ. The VR group outperformed the control in OSATS scoring (p=0.0006). GRS "quality of performance" (p=0.49) and "quality of final product" (p=0.47) domains had higher scores for the VR group. The VR group completed training approximately 155% faster (p=0.008) with an average of two module repetitions and equivalent written scores (p=1.0). The ToT was 32.5% - 59.4% based on comparative completion time and OSATS scores, respectively. The TER was 0.79.

Conclusion: Training senior surgical residents with iVR demonstrated superior learning efficiency and skill transfer measured by ToT. Based on published RTSA learning curves, the iVR module can provide the equivalent of 12-23 operative cases. The TER of 0.79 is higher than prominent surgical simulators and average flight simulators, providing 47.4 minutes of saved OR time for 60 minutes of VR training. Immersive VR should be considered an efficient andeffective means of training medical personnel.

Effective Game-Based Training for Police Officer Decision-Making: Linking Missions, Skills, and Virtual Content

Tim Marler, Susan Straus, Matthew Mizel, John Hollywood, Bob Harrison, Doug Yeung, Kelly Klima, Matthew Lewis, Theresa Kelly, Skip Rizzo, Arno Hartholt, Chris Swain
20456
Often, the development of virtual training environments, specifically games for training, can focus on new technology and content development but insufficiently address underlying training goals. This paper reports the result of a two-year pilot study that developed a framework for implementing low-cost, game-based, virtual reality (VR) technology for training police officers to improve their decision-making under stress. Working closely with partners in the police training community, the study developed a method to ensure virtual training environments reflect intended training goals. This approach maps standard missions undertaken by police officers (e.g., responding to a domestic violence report), to detailed skills and knowledge required by the missions (e.g., communicate effectively at home threshold, assess safety of persons involved in dispute, identify sources of potential risk, actively de-escalate), to implementation within a virtual training environment. Once relevant skills and knowledge were identified, a small number of realistic, compelling training vignettes were developed to represent typical stressful scenarios that require rapid decision-making. These research-based vignettes were then developed into a prototype VR-based training prototype, or a "First-Person-Talker" game to train how to effectively de-escalate a domestic violence mission under stressful conditions. In turn, the prototype VR-scenario was piloted by members of a police department to elicit end-user feedback regarding how effective such a system would be to help officers become more prepared to handle rapidly escalating encounters in the field. Finally, structured methods are presented for deploying the consequent system in the context of current training curricula.

POLICY, STANDARDS, MANAGEMENT, AND ACQUISITION (PSMA)

BEST PAPER

Quantifying Future Return on Investment of Live, Virtual, Constructive Training
Jeffery Bergenthal, William Brobst, Rodney Yerger, Garrett Loeffelman
20282
The United States Marine Corps future shift from predominately live training towards the increased use of Live, Virtual, Constructive (LVC) training will require a significant investment. A capital infusion of this nature demands a quantifiable return on investment (ROI) that justifies increasing LVC training costs. Prior research provides insights into determining the ROI of focused simulation-based training, such as gunnery training, flight training, and medical procedure training. Minimal research has been performed to develop methods for quantifying how the application of LVC in small and large unit collective training can provide cost savings and, more importantly, improved readiness. This paper reports on a study that was performed to quantify the potential ROI of the future Marine Corps Live, Virtual, Constructive Training Environment (LVC-TE). The methodology to determine the ROI metrics used in the study is discussed. Both quantitative ROI metrics, and the data that is required to calculate those metrics, as well as qualitative metrics were used. Examples of qualitative metrics include: training & readiness events that can only be conducted in a synthetic environment, training against a higher end threat, and the ability to train where training and readiness standards do not yet exist (e.g., training in a contested space environment). The results of quantifying the ROI of the LVC-TE are provided and compared against the status quo training. Finally, the paper presents recommendations for developing an LVC-TE training and operations data strategy that outlines the metrics that should be tracked prior to and post LVC-TE fielding to measure the ROI that is being achieved by the LVC-TE.

A new approach to policy: Creating a culture of "Can."
Steve Ellis, Linda Ramirez, Kerry Shows
20213
Creating a culture that enables innovation begins with removing barriers written in policy. In 2018, the SECAF published a series of guidance letters directing the reduction of policy and removing processes to non-directive guides. The Air Education and Training Command has undergone significant changes as a result of this directive. In this paper, we explore best-practices and lessons-learned that we discovered by reducing directive U.S. Air Force technical training guidance from 524 pages to 29 pages through a collaborative development process. Change management processes used both top-down and bottom-up leadership to create what-to-do guidance that lets commanders be commanders and NCOs be NCOs. We migrated the how-to-do information into a knowledge portal that is agile and adaptable to mission needs of our subordinate units. Finally, we explore some examples of innovation that occurred once the restrictions of policy were lifted.

Why are lessons not learned, how can policy and standards ensure data exchange and truly enable lessons to be learned
Francisco Garcia de Paredes
20225
Planning and executing exercises has no meaning if nothing is learned and improved for future military operations. For that reason, most of the western countries and International Organizations have developed their own Lessons Learned (LL) processes, along with their LL tools. The tools might work for the individual Organization, but when they want to share their lessons, or even submit their observations or lessons identified with another Organization, it is often not feasible because of a lack of a common standards for data exchange. This lack of interoperability results in "cut and paste" requirements between systems which discourages the exchange or is very time consuming. The United States for example, wanted to share their lessons from the multinational NATO exercise Trident Juncture 18 with other participating nations. After many efforts it was deemed not possible due to lack of standards and the ability to easily exchange data in the same formats and structure. Also, other nations tried to share lesson learned data from operations and exercises with UN, EU and other partner organizations but the lack of common standards made it complex and time comsuming. In order to address this gap in the interoperability of the different LL tools and systems, the NATO Joint Analysis and Lessons Learned Centre (JALLC) has developed a working form that could be easily adopted by all the NATO countries and partner Organizations ensuring efficient data exchange and ability to truly share data. This paper will outline the present situation, the requirements across our nations and introduce a workable solution developed by JALLC. It will also describe the experiences of capturing LL and ways to ensure these are shared between Organizations resulting in true lessons learned and not lessons identified but not implemented. The LL systems can also be applied to other areas of interest, such as eLearning, simulation,

Data Informed Content Development to Meet Army Simulation Educational Needs
Tammie Smiley, Jamie Pilar, Christopher Herrmann, Walter Watford, Laura Harding
20241
The Army Modeling and Simulation School (AMSS) is continually seeking solutions to better understand and address the US Army's current and emerging analysis, modeling, and simulation educational and training needs. Currently, fundamentals for the use and application of Modeling and Simulation are taught on a general level, however, findings indicate a need for course content customized for specialized needs in the various communities (Medical, Logistics, and Cyber for example). The AMSS continues to gather information for updating and refining the current curriculum with focus on content areas requiring specific expertise.

This paper will capture how the AMSS Analysis Team has utilized a variety of techniques to gather the latest information and concerns from the Army communities in order to stay current and relevant. This effort is currently performed through immersion into 5 major group venues, related workshops and forums, as well as having had the team conduct over 300 individual interviews with multiple government and military personnel, capturing community-specific needs. Major Needs captured have been categorized into 23 areas and have been furthered defined into 52 Critical Tasks. The results have been utilized to develop 3 new courses and educational updates in the areas of Scenario Development, Database Management, and Understanding the Army Communities. In addition, emerging technologies and the continually changing operational focus of Army communities, is creating new demands with unique requirements for training and education.

To continue the refinement of Army educational needs, these findings have demonstrated the need for an up-to-date and relevant curriculum library, listing both government and traditional academia opportunities. Additionally, the value of interpersonal communication and the sharing of resources and ideas among the communities through a centralized learning suite are paramount to continuity throughout all groups over time.

From Silos to Manifolds: Strategies for Improved Learner Record Administration

Ashley Reardon

20247

The ability of modern technologies to generate learner-related data, coupled with an evolution in our understanding of job requirements, has redefined how we can and must learn. The current way learner records are managed in the Department of Defense (DoD) is insufficient for the evolving needs of instructors, learners, and organizations. Today, a transcript is typically used to record learners' permanent academic records. Typically, a transcript only includes the most basic of information such as courses taken, grades received, and degrees conferred from a formal academic institution. Teachers and trainers have little visibility into individuals' past performance, such as what other instructors have noted about them, the informal or nontraditional learning they've experienced, or their strengths, weaknesses, and individual needs.

The Advanced Distributed Learning (ADL) Initiative has participated in several ongoing projects related to learner records. These projects provide opportunities for ADL Initiative staff to engage and leverage lessons-learned and related solutions to ensure the military perspective is accurately and comprehensively represented. Efforts in the academic, military, and workforce domains are being led by the T3 Innovation Network (T3 Network), the American Association of Collegiate Registrars and Admissions Officers (AACRAO), the National Association of Student Personnel Administrators (NASPA), the American Workforce Policy Advisory Board (AWPAB), and the U.S. Air Force through their Airman Learning Record (ALR) project.

This paper will summarize these initiatives with a focus on harmonizing related standards and defining requirements for harnessing DoD learner data across the continuum of lifelong learning. Two broad perspectives emerge in using discoverable and verifiable learner records: the management of individual lifelong learning, and the organizational human capital supply chain. These perspectives point to the need for an approach to interface with existing authoritative learner records in a loosely coupled network, rather than a single stand-alone repository.

Model Based Systems Engineering for Simulator Sustainment

George Ayers, Joseph Doak, Patrick Reynolds, Austin Abraham, Christopher Reed, Marilyn Evans, Carlton Jackson, Buford McCusker, James Sermersheim

20294

Model Based Systems Engineering (MBSE) is a powerful and effective tool for design purposes, but our team believes it also has utility in managing existing systems. The Air Force Materiel Command, Life Cycle Management Center, Agile Combat Support Directorate, Simulators Program Office (AFLCMC/WNS) is responsible for thousands of simulators, of varying degrees of realism, distributed around the world. Additionally, every simulator helps to sharpen the skills of our warfighters in a non-destructive environment so that they will be ready for any high-pressure situation in a real aircraft. Many of these are large and complex Full Flight Simulators (FFS) that cost tens of millions of dollars and have several functions separated into multiple, physically distinct sub-systems. Each FFS has a demanding technical baseline. Each aircraft platform has many FFS technical baselines to manage, and from the enterprise perspective, sustaining this system-of-systems is difficult with documents alone. It is vitally important to maintain awareness and management of all of these technical baselines.

AFLCMC/WNS has launched the Operational Training Infrastructure Enterprise System Model as an innovative MBSE solution to better manage the Simulator Portfolio. This effort has not been without obstacles. First, MBSE is best known for its usefulness in system development; as a result there has been some skepticism that MBSE would not be applicable for a system already in sustainment. Second, the transition from Document Based Systems Engineering to MBSE continues to be met with resistances rooted in established processes, unfamiliarity, and risk aversion. Finally, the experiences of failed efforts in the past to adopt modeling solutions have left some within the organization hesitant to embrace MBSE. This paper discusses how our team plans to use MBSE for simulator sustainment and how the technical and organizational challenges to adopting MBSE in AFLCMC/WNS are being addressed.

Improving Requirements Development Efficiency and Quality with Decision Aids

Paul Butler, Barbara Pemberton, Bill Fetech, Amy Lim, Taylor Talbott, Harry Sotomayor

20296

For the past two years, the U.S. Army Program Executive Office for Simulation, Training, and Instrumentation (PEO STRI) has researched, developed, and is currently implementing an approach for managing project requirements. PEO STRI began by establishing the Requirements Management Working Group (RMWG), an experienced oversight team of requirements engineering subject matter experts (SMEs) and enterprise architects. The RMWG is chartered to facilitate and promote strategic reuse of requirements management assets.

In 2020, the RMWG is developing a requirements decision aid, the Requirements Management Process Model (RMPM). The RMPM assists projects with adopting and adapting enterprise assets – processes, tools, templates, and training materials. This paper describes the RMWG's process for creating the RMPM and how it will be used to identify PEO STRI enterprise assets appropriate for a given project. It defines the relationship between RMPM processes and project management approaches, and presents the planned path forward for prototyping this aid with PEO STRI program managers.

Developing Capability Requirements for Training Systems

Byron Harder

20312

Training system requirements managers have a unique challenge in the form of documenting the qualitative and quantitative requirements of hardware and software systems whose principal purpose is the support of training outcomes for the people that use them. In the United States Department of Defense and similar organizations, capability requirements policies and processes, i.e. the Joint Capabilities Integration and Development System (JCIDS), are oriented on weapon systems. By default, training systems are considered ancillary components of the associated weapon systems. For various reasons, though, some training systems must be developed as independent capabilities rather than footnotes to larger systems. JDICS-type documents consist of two fundamental components: capability requirements, which describe "what" a system must be able to do, and performance attributes, which prescribe threshold and objective (hard minimum and reasonable maximum) measures of "how well" the capability requirements should be met. It turns out that determining performance attributes for training systems can be extremely challenging; typical weapon system attributes such as speed, range, engagement distance, weight, and survivability are essentially meaningless for training systems. The core attribute of a training system is the extent to which it enables training against a set of standards, but those standards can—and must—change as the operating environment evolves. Processes such as JCIDS are not agile enough to respond to changes to the training standards. This paper offers some approaches to determining quantifiable performance attributes for training systems in a JCIDS-type context. It also describes a methodology for adapting requirements at a pace that maintains relevance to the operating environment. Although JCIDS is the main focus, consideration is given to related processes such as Front End Analysis and Training Effectiveness Evaluation. This paper provides tools that will help training system capability developers succeed, even within processes designed for weapon systems.

Innovation Is Ugly: Managing Change in Operational Training Environments

Jennifer Lewis, Joyner Livingston, Diana Pineda

20379

Innovation is the buzzword of the day. Innovation conjures images of bright new ideas and sleek technology. In most cases, though, innovation is ugly. Innovation results in a minimum viable product (MVP) held together with duct tape and bailing wire. It does not work consistently and certainly does not scale. However, innovative ideas do not have to live in skunkworks labs and garages. Properly applied, even the ugliest of innovations serve tangible and valuable purposes in real world, operational systems. Implementing innovations into operational environments in their "ugly" MVP states almost certainly accelerates their adoption or disposal; the latter being just as valuable as the former. During the past three years, applying these types of innovation resulted in faster training times, reduced instructor to student ratios, and improved student engagement within US Air Force, US Army and US Navy undergraduate aviation training programs. This paper describes the program management techniques, ranging from subcontracting, risk management, procurement, stakeholder management, and technical staffing, used to incorporate innovative technologies and methodologies into these programs. The paper also shares significant data points and lessons learned about Agile program management, culture change, and effective large team communication gathered during the execution of these programs.

Metadata in the Future Learning Ecosystem

Yihua Liu

20383

Metadata is becoming increasingly important in the future learning ecosystem. Organizations across the commercial sector, government, and academia are

recognizing the immediate and long-term benefits of metadata implementation. One of the most exciting rewards of metadata implementation is one whose limits have yet to be discovered: unlocking the use of machine learning (ML) and the broader range of other artificial intelligence (AI) capabilities for the education and training domain. These rapidly advancing disciplines promise to enhance operational readiness by making full use of the bounteous data sets continuously produced by modern technology, which are far too vast for humans to interpret. Some of the advancements already enabled by AI include real-time content difficulty adjustment, learning path optimization, and competence estimation. Ongoing research continues to expand the realm of possibility.

Several general-purpose metadata standards currently exist, including the Learning Resource Metadata Initiative (LRMI), Schema.org, the Dublin Core Metadata Initiative (DCMI), and Learning Object Metadata (LOM). Most legacy standards, while they still play an important role, cannot accommodate today's broad range of learning experiences. They often cover only basic attributes and fail to distinguish between various types of learning objects. As the education and training community looks to the future of distributed learning, newer standards must be designed to enable more precise data collection and incorporate non-traditional learning modalities, such as simulations, virtual reality, and mobile content.

This paper summarizes the LRMI Task Group's primary objectives in its efforts to update and combine LRMI and LOM. Because these efforts have led to major revisions, it explains the key upgrades and how they address significant gaps in older standards. Finally, it details the group's technical and strategic recommendations, including the updated standard itself along with implementation guidance to facilitate adoption and transition.

Enterprise Digital Learning Modernization: What, Why, and Who Says So?

Sae Schatz, Amy Rogers, Van Brewer, Kelly Sims, Sharon McMahon
20390

In FY18, in response to Executive Order 13781, DoD established the IT and Business Systems Reform, one of several reforms undertaken by the DoD Chief Management Officer (CMO). The Deputy Secretary of Defense initiated this particular effort in October 2017, encouraging a shift toward DoD-wide enterprise services, IT consolidation, and more efficient DoD business systems. One of the subareas under this reform is Enterprise Digital Learning Modernization.

In July 2018, the Reform Management Group (three star-level Pentagon committee) approved the Enterprise Digital Learning Modernization initiative, including three lines of effort focused on education and training. These include: (1) implement DoD-wide assisted acquisition and category management (i.e., centralized spending oversight) with the Office of Personnel Management (OPM) USALearning program; (2) develop an enterprise course catalog capability; and (3) develop an enterprise learning record repository capacity.

Work on this reform has progressed over the last two years. In April 2019, OPM and DoD signed a memorandum of agreement outlining responsibilities and desired outcomes for the reform. At the same time, DoD CMO issued a memo directing all DoD Components to participate in it. Also in 2019, stakeholders from the Pentagon, Air Force, and OPM began defining technical requirements for the course catalog and learner record repository. And in 2020, senior executives representing education and training perspectives from the military and civilian DoD organizations, and DoD intelligence communities, agreed to serve as an executive steering committee to oversee the reforms and ensure unity of effort across functional communities.

In this paper, we summarize the Enterprise Digital Learning Modernization initiative, including its directives and related polices. We also discuss current and forthcoming guidance about the reform stemming from the Pentagon, and we provide a general update on its implementation progress.

Methodologies applied on LT2 to achieve a long-term strategic vision

Marwane Bahbaz, Benjamin Baker, Rowland Darbin
20405

The U.S. Army Project Manager Soldier Training (PM ST) office has established a legacy of innovation based on the Product Line Engineering methodology to manage a complex System of Systems architecture for live training systems. PM ST has invested in long term initiatives to evolve the Live Training Transformation (LT2) enterprise to meet the future needs of warfighter training. These initiatives resulted in common training capabilities that can expedite the realization of the Synthetic Training Environment (STE) vision as we move from technology exploration efforts to an established foundation of continuously maturing capabilities. Key to this approach is LT2's community accessible approach to advance their core mission though shared capabilities which reduces the "not invented here" mentality. This enables funding to be applied to specifically high value needs instead of redundant solutions common to all training environments (e.g. performance data collection, training specific message exchanges, position location tracking, data retention, data security. Etc.)

This methodology also allows adjacent programs to benefit from existing baseline and focus on their unique needs, LT2 has demonstrated this with the inclusion of the Integrated Live, Virtual, Constructive (LVC) Test Environment (ILTE) system. Most importantly by enabling teams to focus on new capabilities, PM ST established a culture focused on achieving long-term objectives. These concepts are evident in the current enterprise architecture that reaches down to the individual and cloud hosted micro-services for Live Training.

In this paper, we will explain the methodology and framework that PM ST established to support continuous incremental improvement across multiple programs and contractors and the remarkable results achieved through this approach. Additionally we will show how to apply this approach to other programs to achieve similar cost avoidance while implementing their long-term vision.

Demonstrating the Need for Usability Assessment within Software Development Standards

Emily Rickel, Mitchell Tindall, Beth Atkinson, Barbara Chaparro, Emily Anania
20418

Despite the availability of numerous usability assessment methods, current software development practices often lack a user-centered design approach. However, early and continued implementation of usability methods in the software development process can yield significant return on investment by reducing the resources and manpower required to address usability issues, minimizingmaintenance costs and training requirements, and increasinguser efficiency and satisfaction (Rajanen, 2003; Svanes & Gulliksen, 2008). Heuristic evaluation and user testing are two methods that can be used to assess the usability of a product or system. Heuristic evaluation involves assessing an interface against general usability standards (Nielsen & Molich, 1990). Typically performed by individuals with a human factors background, results from heuristic evaluation may not capture data points related to the background and expertise of end-users. User testing fills this gap by collecting feedback directly from end-users as they complete representative scenario-based tasks using the interface under evaluation. These complimentary methods can produce unique results and influence interface design from different approaches to create a more comprehensive evaluation (Tan, Liu, & Bishu, 2009), as seen in the prototype development of Workbench. Currently in development, Workbench is a web-based interface that will be integrated with the Post Mission Assessment for Tactical Training and Trend Analysis (PMATT-TA) software suite. PMATT-TA supports anti-submarine warfare (ASW) training assessments by providing a central location for the collection, aggregation, and visualization of ASW measures of performance (MOPs). Workbench aims to establish a more efficient process for training instructors to update and create MOPs without the assistance of a software engineer. This paper will compare the protocols and recommendations associated with heuristic evaluation and user testing as they apply to the Workbench case study. These results can be usedto demonstrate and justify the need for standardized, iterative, user-centered design software development processes when creating training systems.

Preparing for the future of war - M&S driven operational exercises in support of Joint All-Domain Command and Control

Joshua Fuller
20423

Operational-level M&S receives little fanfare or attention; but the role of M&S driven operational exercises cannot be understated, particularly as Joint All-Domain C2 emerges from concept to fundamental doctrine and capabilities.

Simulating combat outcomes within a single domain, and then across domains via various methods of federation, has become a matter of math between available development resources and "good enough" fidelity to achieve training outcomes. To this extent, realism within M&S-driven operational exercises takes a back-seat to a "train-to-process" mindset that does not place a focus on a win-or-lose outcome. Layered between the operational sim and the training audience is a host of functional cells that interpret and craft the battlefield environment, and sets stages for the scenario to progress through. This has led to exercise planners fielding complaints that our exercises are not developing tactics and procedures that can be relied upon in wartime.

This paper provides examples to portray critical capability gaps in our ability to conduct all-domain exercises, and presents the challenges inherent in current operational simulations that may prevent us from fully realizing the ability of the operational HQs to train and win across all domains. There are several facets of this problem that this paper explores. Why is a level of realism needed at the operational level, and does this increased realism demand higher-fidelity simulations or higher-fidelity outputs and outcomes? What will joint all-domain doctrine demand? Can we continue process-oriented training or do we need greater realism and fidelity to create better instinctual application of Joint All-Domain C2? To conclude, this paper conceptualizes proposals for industry, policymakers and acquisition programs to grow operational M&S capabilities.

Advancing the Research Agenda for the Modeling, Simulation, and Training Community

Eric Weisel, Brian Goldiez, Saikou Diallo, Fuzzy Wells, Curtis Blais
20465

A community's research agenda is a set of topics, objectives, and open questions that influence investment choices, usually in time and money, made by researchers, funders, policy-makers, and legislators. The modeling, simulation, and training (MS&T) community has invested significant resources, mostly through voluntary contributions of time, to identify science and technology challenges that slow the advance of the discipline. Past attempts to achieve a broad consensus within the community on the most important research questions have suffered from a conflation of MS&T and application area science objectives. This paper surveys prior contributions, describes a new approach to the research agenda, and reports on an NTSA-sponsored meeting of members from the academic MS&T research community, held in conjunction with the 2019 MODSIM World Conference, and charged to identify programs of research that will keep the community at the forefront of technological and methodological innovation. Fourteen organizations, spanning most of the universities that offer MS&T programs or degrees, participated in the MODSIM meeting, or provided substantive input directly to the organizer. The new approach, exercised there, involved finding those problems that the MS&T community cares about more than anyone else, prioritizing research topics that 'we own' as a discipline without regard to application area. Recommended initiatives were grouped into three distinct categories; research areas unique to the MS&T community, research topics in related disciplines that impact MS&T priorities, and research topics that would benefit from collaborative research with other communities. A key finding from the MODSIM workshop is that this approach will allow the community to focus awareness on core MS&T challenges, those that most clearly differentiate MS&T from other disciples that use models and simulations in course of their science, while collaborating with the broader community of science and reaping benefit from MS&T-relevant science and technology advances at-large.

VV&A Redux: The Case for Considering 4E Cognition

Nick Armendariz, Patricia Bockelman
20475

Since the early days of Verification and Validation, to the addition of Accreditation in the VV&A process, the goal has been to determine the return on investment (ROI) to the gaining organization of a particular system by evaluating the system against it's intended purpose and design. As simulation-based training and learning technologies have continued to advance at a leap-ahead pace, the process utilized to evaluate them has not maintained pace with the advancements in cognitive science. In particular, the gains in understanding of how cognition occurs as part of the overall learning process. 4E cognition ties together the areas of embedded, embodied, extended, and enactive cognition to form a comprehensive view of how these processes incorporate multiple areas of cognition, with the mind, body, and environment surrounding the learner to provide an enriched learning experience. This must be taken into account during evaluative processes, such as VV&A in order to identify true markers of ROI, in addition to marking areas for efficiency potential by realizing which areas of cognition are being most engaged by the system or technology in question. This is especially important with simulation based training systems due to the varied levels of involvement of the mind, body, and physical environment during the learning experience. This paper will demonstrate areas of improvement to current and disparate DoD policies that govern and guide the VV&A processes for the service components and lay the foundation for the need to incorporate 4E cognition into these processes. Understanding how cognition ties into the learning process can assist in providing more efficient evalution of the training systems of the future.

Re-Thinking the Tactical Small Unit Synthetic Training Model

Kevin Owens, Benjamin Goldberg, Kevin Owens, Kevin Hellman
20476

Military close-combat is an environment characterized by tactical small-unit (TSU) infantry engaging with extreme violence within line-of-sight of an enemy. Close-combat during the last-two wars in Iraq and Afghanistan often resulted in many casualties as a result of "fair fights" (Mattis, 2016) against a relatively inferior, ill-equipped but extremely fanatic opposing force. Such combat effectiveness "matching" should not happen with the investment in technology and training provided to our soldiers.

Historically 90% of all US forces combat casualties in wars over the last eight-decades occur during tactical small-unit (TSU) infantry close-combat (Roper, 2018). In future warfare, precision long-range enemy firepower will expand and dominate battlefields, supported by a proliferation of cheap high resolution battlefield sensors. This condition may essentially eliminate the element of traditional large force surprise and linear maneuver against "near-peer" enemies (Scales, 2019). As such, an Army's general infantry TSU force may become the main thrust of decentralized maneuver. However, based on historic casualty trends with these forces, Army's will be severely challenged to sustain themselves in a prolonged war without gaining overmatch with enemy forces. "Overmatch" is here-in characterized as TSU competency levels equal or near that of today's Ranger unit or in some areas, Special Forces levels.

This paper will discuss capabilities and use-cases being designed for the future Synthetic Training Environment (STE) – Training Management Tools (TMT) to support achieving the above use-case, in conjunction with key policy changes required in Army training doctrine. The goal is to provide a vision how STE-TMT will support the US Army's effort to build, sustain and replace the lethality and overmatch of its current and future TSU levels. This paper will also discuss using modern competency based experiential assessment, using a data-driven and experiential expertise based strategy for achieving combat readiness.

SIMULATION

BEST PAPER

Virtual Living Room: Bridging the Physical Distance with Virtual Reality

Andrew Rukangu, Kelsey Mattingly, Anton Franzluebbers, Alexander Tuttle, Catherine O'Neal, Dawn Robinson, Sun Joo (Grace) Ahn, Kyle Johnsen
20355

The efficacy of VR in training applications is well documented in the simulation community, and VR efficacy is being increasingly demonstrated in other applications such as mental health therapy, industrial design, and other collaborative activities. This paper describes a collaborative application of VR that has a positive impact on warfighter readiness outside of the training environment.

The Virtual Living Room provides deployed warfighters the opportunity for meaningful interactions with family members who are at physically remote locations back home. The deployed warfighter shares the same virtual environment as their family members and plays family-oriented games (e.g., block builder), share recreational activities (e.g., mini-golf), or engage in collaborative work (e.g., homework). The Virtual Family Room has an advantage over passive communication technologies, like video chat, because it provides an increased sense of participation and engagement, as well as allowing the whole family to share experiences rather than passive information. These effects are particularly important for young children who lack the ability to engage in complex verbal communication.

The efficacy of the Virtual Family Room was assessed with a military family at a United States installation. The participant was not deployed, but was preparing for deployment, and had prior deployment experiences. After initial system training, the family could participate in any of the virtual activities of their choosing. The family members were physically separated during the sessions, and the sessions were recorded. Data were collected on the perceptions of the overall experience, enjoyment of the virtual activities, and input on possible improvements. The results indicated that the family interactions were more "realistic" than video chat and that the virtual activities

provided more memorable experiences for the families. The Virtual Family Room demonstrates the usefulness of VR in bridging the gap between families during deployments and, thereby, increasing warfighter readiness.

Semantic Segmentation and Data Fusion of Microsoft Bing 3D Cities and Small UAV-based Photogrammetric Data

Meida Chen, Andrew Feng, Kyle McCullough, Pratusha Bhuvana-Prasad, Ryan McAlinden, Lucio Soibelman

20220

With the state-of-the-art sensing and photogrammetric techniques, Microsoft Bing Maps team has created over 125 highly detailed 3D cities from 11 different countries that cover hundreds of thousands of square km areas. The 3D city models were created using the photogrammetric technique with high-resolution images that were captured from aircraft-mounted cameras. Such a large 3D city database has caught the attention of the U.S. Army for creating virtual simulation environments to support military operations. However, the 3D city models do not have semantic information such as buildings, vegetation, and ground and cannot allow sophisticated user-level and system-level interaction. At I/ITSEC 2019, the authors presented a fully automated data segmentation and object information extraction framework for creating simulation terrain using UAV-based photogrammetric data (Chen et al. 2019). This paper discusses the next steps in extending our designed data segmentation framework for segmenting 3D city data from Microsoft Bing. In this study, the authors first investigated the strengths and limitations of the existing framework when applied to Microsoft Bing data. The main differences between UAV-based and aircraft-based photogrammetric data are highlighted. The data quality issues in the aircraft-based photogrammetric data, which can negatively affect the segmentation performance are identified. Based on the findings, A workflow was designed specifically for segmenting Microsoft Bing data while considering its data characteristics. In addition, since the ultimate goal is to combine the use of both small UAV collected data and the Microsoft Bing data in a virtual simulation environment, data from these two sources need to be aligned/registered together. To this end, the authors also proposed a data registration workflow that utilized the traditional iterative closest point (ICP) with the extracted semantic information.

Generating Synthetic Photogrammetric Data for Training Deep Learning based 3D Point Cloud Segmentation Models

Meida Chen, Andrew Feng, Kyle McCullough, Pratusha Bhuvana-Prasad, Ryan McAlinden, Lucio Soibelman

20221

At I/ITSEC 2019, the authors presented a fully-automated workflow to segment photogrammetric 3D point clouds/meshes and extract object information, including individual tree locations and ground materials (Chen et al. 2019). The ultimate goal is to create realistic virtual environments and provide the necessary information for simulation. The generalizability of the previously proposed framework was tested using a database that was created under the Army's One World Terrain (OWT) project with a variety of landscapes (i.e., various buildings styles, types of vegetation, and urban density) and different data qualities (i.e., flight altitudes and overlap between images). Although the database is considerably larger than existing databases, it remains unknown whether deep learning algorithms have truly achieved their full potential in terms of accuracy, as sizable data sets for training and validation are currently lacking. Obtaining large annotated 3D point cloud and 2D image databases are time-consuming and labor-intensive not only from a data annotation perspective in which the data must be manually labeled by well-trained personnel but also from a raw data collection and processing perspective. Furthermore, it is generally difficult for segmentation models to differentiate objects, such as buildings and tree masses, and these types of scenarios do not always exist in the collected data set. Thus, the objective of this study is to investigate the possibility of using synthetic photogrammetric data to substitute for real-world data in training deep learning algorithms. The author has investigated methods for generating synthetic UAV-based photogrammetric data to provide a sufficiently sized database for training a deep learning algorithm with the ability to enlarge the data size for scenarios in which deep learning models have difficulties.

Using Visual Analytics to Manage Experimental Frames

Rob Barwell, Peter Dobias

20223

Operational problems often span wide range of options. In the past, due to computational limitations, the trend was to limit the options set to the minimum number possible. However, with the increase in computational capacity over the last decade, it is now often possible to parametrize the option space instead, and simulate hundred or even thousands of options. One of the first attempts in the defence domain was the US Marine Corps Project Albert which looked at data farming in tactical combat modeling. However, simulating vast numbers of options poses new challenges for managing experiments and conducting post-simulation analysis. Some of the model management challenges are: which simulations have been conducted, what option space has or has not been explored, which output maps to which input, etc. The analysis problems include considerations such as what model inputs typically lead to what model outputs, whether the results covering a subset of possible options are sufficiently representative for the entire set of possibilities, and how to visualize dependences on the inputs in multi-dimensional problems. This paper will focus on combining the field of visual analytics with modeling and simulation for a, somewhat simplified, problem of strategic air lift. Using this problem, that can be summarized as: "what is the force structure requirement for the strategic airlift to meet logistics demand of concurrent operations as mandated by the Government of Canada's defense policy Strong, Secure, Engaged?", the paper will look at the management of the experimental frames for simulation, option space coverage, and visual analytics applications to the output. Common visualizations approaches such as generalized pairs plots, maps, as well as 3D visualization will be exploited to provide an innovative experimentation management and analytics framework.

Generating Connected Synthetic Electronic Health Records and Social Media Data for Modeling and Simulation

Anne Tall, Cliff Zou, Jun Wang

20243

Research and experimentation using big data sets, specifically large sets of electronic health records (EHR) and social media data, is demonstrating the potential to understand the spread of diseases and a variety of other issues. Applications of advanced algorithms, machine learning, and artificial intelligence indicate a potential for rapidly advancing improvements in public health. For example, several reports indicate that social media data can be used to predict disease outbreak and spread (Brown, 2015). Since real-world EHR data has complicated security and privacy issues preventing it from being widely used by researchers, there is a real need to synthetically generate EHR data that is realistic and representative. Current EHR generators, such as Syntheaä (Walonoski et al., 2018) only simulate and generate pure medical-related data. However, adding patients' social media data with their simulated EHR data would make combined data more comprehensive and realistic for healthcare research.

This paper presents a patients' social media data generator that extends an EHR data generator. By adding coherent social media data to EHR data, a variety of issues can be examined for emerging interests, such as where a contagious patient may have been and others with whom they may have been in contact. Social media data, specifically Twitter data, is generated with phrases indicating the onset of symptoms corresponding to the synthetically generated EHR reports of simulated patients. This enables creation of an open data set that is scalable up to a big-data size, and is not subject to the security, privacy concerns, and restrictions of real healthcare data sets. This capability is important to the modeling and simulation community, such as scientists and epidemiologists who are developing algorithms to analyze the spread of diseases. It enables testing a variety of analytics without revealing real-world private patient information.

Predictive Performance Modeling for Distributed Live, Virtual, Constructive Environments

Rebecca Cebulka

20261

Modern distributed simulations require a substantial network infrastructure – be it satellite links, broadband internet, radio communications, or a mix of all of these. Modern, large-scale live, virtual, constructive (LVC) simulations may require high numbers both of human-in-the-loop participants and constructed physical entities, each of which must communicate in some way with the others. Thus, when planning and executing a large-scale distributed LVC simulation it is extremely beneficial to have a good idea of whether your network is capable of facilitating the necessary data transfer and communications quickly enough to enable real-time reactions to perform the particular mission. We aim to provide a government-developed modeling and simulation tool which will allow predictions of an arbitrary network's data transfer and communication capability, extensible to eventually include computational capability predictions. Currently, we are able to simulate an arbitrary number of applications and users interacting via simulation processes submitting jobs by broadcast and multicast methods through a specified network infrastructure to be analyzed on remote servers, with both RAM and SSD elements, jitter functionality, propagation delays, and network loading due to various real-world properties. Each link between network elements has a specified propagation delay (artificial latency), maximum transmission unit, and bandwidth. These elements are particularly important, as excessive latency can be greatly detrimental to the processing requirements of large-scale distributed simulation events. We believe that the behavior of the model as the network parameters are varied is reasonable, and that this model could be useful in predicting capabilities of larger distributed networks. We support

this conclusion with data taken from a small test network architecture modelled after a development enclave in our lab.

Cross Domain Security in Airpower Mission Training through Distributed Simulation

Manfred Roza, Arjan Lemmers, James Quarmyne, Peter Van Onzenoort
20265

Airpower Mission Training through Distributed Simulation (MTDS) is becoming a crucial capability for Air Forces to satisfy their coalition collective training needs. In these MTDS capabilities simulation assets from different security domains must be able to interoperate effectively and efficiently within a single training exercise. Cross domain solutions (CDS) are a common to tackle such security issues in the C4ISR domain. However CDS specifically designed for MTDS assets are rare, though MTDS imposes unique requirements on such solutions. The returning key challenges are: to what extend can simulation data be degraded while not compromising training value and reducing the risk of unwanted information leakage into another domain to an acceptable minimum.

Currently, the Royal Netherlands Airspace Centre NLR is developing the theoretical and practical foundations for a cross domain solution to support the Royal Netherlands Air Force (RNLAF) in their needs to interoperate national classified simulation training capabilities of various levels within a single distributed mission training environment, as well as in joint mission training with NATO coalition partners. For this purpose NLR is actively participating in NATO MSG 165 task group on the Incremental Implementation of MTDS for Joint and Combined Air Operations.

The paper will introduce a conceptual framework that provides the fundamental and general applicable CDS terminology, semantics, concepts and principles related to Airpower MTDS. The framework facilitates the communication, understanding and implementation of CDS within the simulation domain. It provides the core foundations upon which NLR's secure simulation interoperability testbed rest, which will be outlined next in this paper. Finally, several possible CDS implementation designs and the lessons learned from their experimentational evaluation will be discussed in the third part. In here the focus lays on the real-time simulation performance impact, level of training fidelity and value, and information leakage risks in Airpower MTDS exercises.

A Novel Approach to Medical Team Training: Blended Reality Built on Open Source Platforms

Rachel Wentz, Teresita Sotomayor, Daniel Silverglate
20266

One of the most effective means of reducing medical errors is through good communication. The Immersive Modular Patient Care Team Trainer (IMPACTT) project is funded by DHA/JPC-1 in conjunction with Army Futures Command. Initially targeting pre-deployment medical teams, it is designed to address gaps in team training, specifically, ways to improve communication and enhance performance of teams working in emergency rooms and austere environments. This multi-user training simulation runs on commercial tablet computers and is built on the open source Advanced Modular Manikin (AMM™) platform. Using touchscreen tablets, learners assess and treat interactive 3D virtual patients suffering from multi-system trauma. Players select the appropriate Advanced Trauma Life Support® (ATLS) interventions from radial menus on their screen and, since the virtual patients' physiology is driven by Biogears® Open Source Physiology Engine, their vital signs, behavior, and appearance improve or deteriorate, based on the appropriateness and timeliness of each treatment. The program supports a range of practitioners (doctors, nurses, techs, or respiratory techs). The virtual patient is displayed on each players' tablet, as well as on a shared large screen. A separate array of tablets serves as virtual medical equipment, to include a patient monitor, IV pump, ventilator, labs, and a urine meter, making the system affordable and portable. Hands-on interventions, such as establishing vascular access (IV/IO) or intubating the patient, can be performed virtually or via an AMM-compliant part-task trainer, making the system scalable, based on learner needs. During virtual interventions, the player is presented with a task-specific cognitive exercise that engages them for the time it would normally take to perform the intervention. The IMPACTT system is designed to improve team communication and enhance performance, thereby reducing life-threatening medical errors in emergency settings. This paper will discuss implementation of this blended reality training capability, its challenges, lessons learned, and future applications.

Collaborative Development of Synthetic Task Environment by Academia and Military

Summer Rebensky, Meredith Carroll, Wink Bennett, Xueyu Hu
20267

Synthetic Task Environments (STEs) can allow for low-cost and efficient ways to conduct research and provide training compared to live training. However, university researchers, particularly graduate students, often lack resources to develop STEs for research and educational purposes. The accessibility of commercially-available software, like game development engines, allows for the rapid development of STEs. These software platforms allow for the creation of complex environments with limited development expertise. This paper will discuss a collaborative effort between Florida Institute of Technology (FIT) and the Air Force Research Lab's Gaming Research Integration for Learning Laboratory (GRILL) to develop a small Unmanned Aircraft System (sUAS) STE for a search task. The development utilized Unreal Engine to develop the STE in less than nine weeks. The STE consisted of grassland environment, a sUAS with a full interface to complete a sUAS led search and rescue mission. The FIT graduate student led the upfront analysis for the STE, including sUAS operational issues, task analyses utilizing Subject Matter Experts (SMEs), and requirements for the STE. The graduate student then spent a five-week period over the summer co-located with the GRILL and led a team of high school student interns, with daily mentorship from a GRILL software engineer, in development of the STE. This period allowed for rapid buildout of a sUAS environment with the following attributes: (a) high cognitive fidelity with respect to a UAS search task, (b) flexible interfaces for researchers to alter STE parameters, (c) integrated research tools such as questionnaires, (d) fully customizable mission characteristics, and (e) tailored output files for streamlined data analyses. The result was a sUAS STE that allowed for tailored research efforts at FIT and proof of concept technology for the GRILL. This presentation will describe the collaborative process, methods, and recommendations for other entities pursuing collaborative development efforts.

Methodology to Utilize Pre-Computed Voronoi Diagrams to Enable Dynamic Deformation and Destructibility of Environmental Meshes Within A Simulation Environment

Ryan McAlinden, Noah Nam, Kyle McCullough, Raymond New
20270

Runtime environments commonly use "sleight-of-hand" techniques to approximate destruction and convince a user that their actions have deformed or destroyed an object. These "sleight-of-hand" processes rely on hand-creating general-use "pre-shattered" objects that may not accurately reflect the effects of every explosion, given the possible variations in radius and force. In a simulation, munitions must deform and fragment the environment believably in order to provide analysis and visual feedback to the users. At I/ITSEC 2019, the authors explored methodologies for increasing the number of autonomous entities within a simulation using existing game industry solutions. For this work, the authors have utilized a similar approach to mesh deformation by exploring the commercial game industry and attempting to capitalize on existing methods, while taking into account the necessity for removing the human-in-the-loop required by those techniques. With the global coverage of environment meshes expected to be used in the Synthetic Training Environment (STE), it would be too time consuming to create each mesh's destroyed variants by hand. In order to overcome this challenge, we have explored a method of using precomputed Voronoi diagrams to deform and fragment 3D meshes in real-time while maintaining performant simulation speed and fidelity. This method allows destruction to be customized to specific scales and positions on a given mesh based on the type and location of an ordnance. Utilizing additional research presented at I/ITSEC 2019 for creating simulation terrain (Chen et al. 2019) the workflow takes into account semantic classification enabling the system to deform ground meshes into craters and support attributed material types (e.g. concrete, wood) for object mesh fragmentation. With this research, we can bypass a lengthy process of manually preparing destruction meshes while also having a destruction system decoupled from mesh generation; both systems can be independently updated without requiring modification of the other.

Never feed it after midnight – Testing un-intended consequences in simulation

Nicholas Moylan
20285

Developing and deploying complex systems can be highly challenging, particularly with the issue of un-intended or emergent behaviours. Existing test methods are well adapted to low level test, demonstrating the performance of components in their un-integrated state, or high level demonstrations of integrated systems, but which lack the depth of test to find and fix emergent behaviours, particularly where those may be introduced by influences outside the system of interest. This is particularly important where the safe operation of the system matters to those who mission matters.

One such complex system is autonomous vehicles. This paper will seek to discuss the issues of identifying the impact of emergent behaviours, and approaches to verifying safe performance of complex systems in the real world, by testing in the synthetic environment. This paper will build upon the

findings of the OmniCAV programme in verifying the safe behaviour of an autonomous vehicle and draw parallels with other complex systems used in defence.

OmniCAV is a consortium project that is partly funded by the UK Government. It aims to deliver a highly realistic simulation environment for AV stack verification that considers all road users and road types. The programme has developed a unique synthetic environment integrating a high fidelity survey of urban and rural Oxfordshire, with other simulated road users allowing all conditions to be simulated and evaluated. This is being delivered in combination with real-world testing to support the assurance of the safety case for deploying a self-driving car. As well as XPI's work on OmniCAV, potential approaches for integrating multi-part simulators for generating coherent and rich digital twins associated with such autonomous systems testing will be addressed.

In concluding, some of the key technical challenges that remain in this domain will be identified, including interpretation of results and assuring completeness of testing.

Addressing Tactical Combat Casualty Care in Synthetic Training Environments

Richard Madrid, William Pike, Paul Cummings, Joanne Barnieu
20317

As of 2010, 90% of US service men and women who die from combat wounds do so before arriving at a medical treatment facility (Eastridge, 2012). This fact highlights the importance of battlefield trauma care provided by combat medics, corpsmen, and nonmedical unit members in improving combat-wounded survival rates. For Tactical Combat Care (TC3) mastery, curriculum should be enhanced to address higher levels of learning within the cognitive and psychomotor learning domains required for complex situations, (i.e., care under fire), which include skills related to spatial awareness, marksmanship, movement, communication and decision making under stress. To address instruction and assessment of these skills, the US Army Combat Capabilities Development Command developed a TC3-based training prototype that incorporates multiple hybrid virtual and augmented display systems, simulated weapons, and haptic devices. The paper describes the design, development, and research processes used to produce the TC3 training system. We present a formalized process for developing three training vignettes; each are a) learning objective-driven, b) rooted in task and human factors analyses, and c) integrated with multiple haptics, virtual reality (VR), augmented reality (AR) and mixed reality (MR) systems. We discuss our research-based usability study targeting multiple potential user communities practicing point of injury care procedures in a VR environment integrated with haptics gloves. While technologies employed are early in the development process, results indicate a positive experience from all tested user communities. This research effort reinforces the notion that TC3 mastery will be a key component to the design and development of next-generation synthetic training environment systems.

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Rapid Simulation Model Development for Computer Generated Forces

Jackie Zhang
20329

Computer Generated Forces (CGF) simulations use physical models as the basic components of simulated entities, which contain mathematical representation of combat systems and their interactions with the environment and other simulated entities, therefore it is essential that they should be built using authoritative data to provide realistic physical dynamics. However, the development of such validated models is resource intensive because of the complex data representation and mathematical implementation. With military's increasing LVC integrated simulation training requirements, the concept of building validated physical models once and allowing different types of simulation systems to use/reuse these precalculated model data as needed is more attractive than ever.

Validated physical models can be from different domains and disciplines with different format and standards. The mathematical formulas are designed to use the ground-truth data to produce meaningful data values that a simulation system can use to simulate entities. A proof of concept development of Rapid Simulation Model Development (RSMD) Toolkit implemented a physical modeling process by using United States Army Materiel Systems Analysis Activity (AMSAA) validated physical models stored in Physical Knowledge Acquisition Documents (PKADs). The RSMD's framework entrusted Modular Open Systems Approach (MOSA) compliant technologies by plugging in the PKADs as an authoritative data source, constructed several physical models for the machine gun M-16, and produced a set of validated physical data which was consumed by the M-16 entity simulated in a well know CGF system named VR-Forces.

The physical models implemented were Direct Fire Weapon Accuracy, Rate of Fire, and Direct Fire Weapon Characteristics. The VR-Forces M-16 scenario that used the validated data showed a statistically significant enhancement in the gun's hit and miss calculation while the architecture ensures multiple data sources and simulation engines can be plugged into or removed from the architecture as needed. This paper provides the statistical improvements found in our study and the software architecture design methodologies.

Turning Real World Objects into Photorealistic One Poly Models

Jonathan Bishop, Darren Flowers-Finley
20365

Striving for the best looking database content for the lowest impact on time and money is challenging. Improving the visual standard of models using modern techniques and methods, while keeping in mind polygon count and texture space requirements, produces models that look how they should in the real world. The level of detail (LODs) involved with building from the model and using current methods can be arduous, time consuming and expensive. Models in the simulation industry have a below par visual fidelity compared to other industries, such as the gaming and theme park industries. Comparatively, the processes to create these models takes a substantial amount of time and dollars. If the simulation industry were able to obtain the same or better visual fidelity as these other industries, while reducing development costs and time, yet maintaining performance; a new era of simulation would emerge.

In the simulation industry today, models and their LODs are created using outdated methods, which is time consuming and visually less appealing. Using modern software, and a clever use of physical and virtual cameras; a photorealistic model can be created and integrated with a new and innovative process for LODs. The method of creating photorealistic models is called Photogrammetry and the new LOD method uses a technique called Impostors. Photogrammetry creates a hyper realistic model, when the eyepoint is close, giving the high fidelity capability. Impostors maintain that visual standard when the eyepoint is far away from the object for a fraction of the performance cost allowing more objects to be drawn at any given time. These methods can create models from scratch in a matter of hours versus weeks. Additionally, this allows for quicker iterations on newer projects and more efficient ways of altering models down the road; which in turn saves time and money.

Population Migration Decision-Making

Neil Sleevi, Steven Hall, Jumanne Donahue, Matthew Zefferman, Susan Aros, Anne Marie Baylouni
20380

The risk of adversaries instigating mass human migration, refugee flows and crowd formations in the battlespace requires mitigation because unexpected population movements can adversely impact the United States and its partners' operations abroad. Even relatively small gatherings of non-combatants, especially at urban choke points can have repercussions that impact military operations which may rely on smooth traffic flow within a city's roads and infrastructure. Simulation in the field of Pattern of Life Analytics is critically important to the military because it may lead to improvements in predicting patterns of movement and other behaviors that are realistic, reliable, and repeatable among non-military populations. To date there has been insufficient modeling of the representation of the political, economic and social conditions within the operational environment (OE) and effects on combatants and noncombatants. The Army Studies Program funded the Naval Postgraduate School (NPS) to work in 2019 with TRADOC G-2 Modeling and Simulations to develop a methodology and model for population migration to simulate and predict non-combatant movement and identify potential impacts in the OE. The combination of NPS' SMDM and the Army's Athena models provided unique insights to OE characterization, risk assessment, synchronization, and course of action development. The lessons learned from results of using SMDM to provide anticipatory analytics for noncombatant population migration in the battle space have enabled improved modeling of noncombatant population migrations and tipping points. This means that as future information operations and physical events are initiated by adversaries in an area, this work will allow a better understanding of first and second order impacts of non-combatant population movement in the battlespace. Lessons learned from this work will highlight how to better simulate and predict non-combatant movement and identify potential impacts in the OE using the methodologies developed in this important effort.

The Common Image Generator Interface - Is it Really?

Sean Duff, Kenny Dixon

20382

The Common Image Generator Interface (CIGI) is a communication protocol standardized by the Simulation Interoperability Standards Organization (SISO) under SISO-STD-013-2014, Standard for Common Image Generator Interface (CIGI), Version 4.0, dated 22 August 2014. The SISO Product Support Group page for CIGI states, "The purpose of CIGI is to provide interoperability across real-time Image Generator (IG) and Host computational system providers by using a common method of communications. The product will provide a common communications protocol that will enable each disparate visualization tool to quickly interface with other subsystems by providing a set of commonly used subsystem-to-subsystem interactions." This design goal has led some branches of the United States Armed Forces to include the use of CIGI as a requirement when procuring new simulation devices over the past decade and a half. This paper analyzes the success of the CIGI initiative by examining the integration costs and program impacts when upgrading visual systems. Over the past 15 years, the US Navy has issued multiple contracts to build and upgrade MH-60R and MH-60S operational flight trainers for both the US Navy and foreign military customers. Across these various contracts, the flight trainers have been integrated with three different Image Generators (IGs) from three different vendors, all while satisfying the requirement to use the CIGI standard for host to IG communication. This paper will discuss the instances where the CIGI requirement did in fact increase reusability and efficiency across the separate efforts. The paper will also demonstrate where this requirement failed to reduce integration costs. Finally, this paper will discuss opportunities for the CIGI standard, as well as procurement agencies, to improve and truly achieve the goal of reduced integration costs.

Using a Design Structure Matrix for Representing Network Topologies

Andrew Hand

20384

In Authority To Operate (ATO) packages, cybersecurity network connectivity is often represented with a Visio Diagram to identify connectivity between computers and logical groupings of these computers into subsystems. While the information provided on these diagrams is incredibly useful, the Design Structure Matrix (DSM) provides an alternative way to represent the architecture of a system, with a particular focus on the interfaces between systems. Instead of complicated diagrams spanning sheets of drawings (as with a standard topology diagram), the DSM can represent the interconnectivity of the computers within a single table. More importantly, the DSM makes available a set of tools for grouping subsystems systematically (or even programmatically) and provides a way to highlight the scanning coverage of each computer system in the same, compact format.

The DSM is a Model Based Systems Engineering tool that allows for a more logical architecture of complex systems and has been used on aerospace and defense systems with great success.

This paper examines the advantages and disadvantages of using a DSM as an alternative to a Visio Topology Diagram, and as a supplement to a Visio Topology diagram. The systematic process of grouping subsystems is demonstrated with a generic Training System architecture for a training center featuring several simulators of different configurations, including full flight simulators. This paper also explores the possibility of using a DSM during the design process to recommend alternative topologies for training systems and simulator architectures. Detailed examples are given of non-specific architectures.

This paper is important to the simulator community, because it provides an innovative way to approach an often time-consuming problem of developing network topologies and provides a systematic method for grouping modules of computer systems within network groups."

Physics-Based, Multi-Modal Synthetic Human Image Generator

Huaining Cheng, Devendra Tolani, Zhiqing Cheng, John Kerekes, Eric van Doorn, Mun Wai Lee, Daniel Ashley, Gang Mei, Roger Xu, Nina Raqueno

20389

There is a need to develop a physics based 3D modeling and simulation (M&S) software to generate multi-modal datasets for machine learning of human activity detection and recognition, due to the high cost and difficulty in collecting of synchronized, multi-view human sensing data. This paper presents the effort in developing a novel, integrated, high-fidelity M&S tool: HumanView (HumV) of human signatures. Its key elements include: (a) HumV editor module, which allows users to view and manage available models and associated configurations using intuitive graphical user interface; (b) HumV models module, which is a data store containing human models, scene models of environment, and relevant electro-optical/infrared (EO/IR) sensor models; and (c) HumV simulator module, which allows users to simulate multiple scenarios for generation of synthetic sensor data and truth labels for analytics. HumV builds a pipeline that seamlessly integrates off-the-shelf free and open-source multi-physics M&S tools and material properties databases with the newly developed models and algorithms to address the multi-disciplinary M&S requirements. Specifically, we developed the Human Activity Replication Tool (HART) – a Blender 3D add-on to provide bio-fidelic M&S of clothed avatars that realistically represent the diversity of human shape, motion, and clothing characteristics. This is followed up by an innovative human thermal model that takes the scene and HART activity models to produce an output of temperature estimates for all the mesh facets of skin and clothing of the human avatars. The thermal dynamics considers the activity/heart rate, environmental radiance, and body/clothing interaction. Finally the various models of human activity, thermal dynamics, scene, materials, environment, sensor, and atmosphere are assembled into the Digital Imaging and Remote Sensing Image Generation (DIRSIG) tool to generate synthetic images or videos. A model validation has been conducted against the experimental data collected using commercial cameras at an outdoor setting.

Semantics-Aware 3D Segmentation and Modeling System for Immersive Simulations and Training Scenarios

Anil Usumezbas, Bogdan Matei, Rakesh Kumar, Supun Samarasekera

20400

In recent years, 3D sensors have become increasingly ubiquitous, along with algorithms for integrating the measurements of these sensors over time to produce detailed and high-fidelity 3D models of both indoor and outdoor scenes. As large-scale 3D models become easier and cheaper to produce but remain prohibitively large and cumbersome, the emphasis has been slowly shifting from model production to effective storage, transfer, visualization and processing of these models, as well as their ease-of-use when a human agent is interacting with them. To this end, we propose a novel and fully-automated system for understanding the distinct components of a 3D scene and the contextual interactions between such components in order to get a better understanding of the scene contents and to segment the scene into various semantic categories of interest. Imbuing existing 3D models with such semantic attributes is an important first step in the broader 3D scene understanding problem, allowing automatic identification of different objects, parts of objects or types of terrain, which in turn allows for these categories to be targeted separately by simulation frameworks as well as various downstream processes. We show that through the use of these semantic attributes, it is possible to i) generate significantly more compact models without drastic degradations in quality and fidelity, allowing the targeting of mobile platforms with limited computational capabilities, ii) improve localization accuracy when estimating the full 6-DOF pose of a mobile agent situated in the scene, and iii) provide human agents with richer and smoother interactions with such 3D models during simulations and training scenarios.

Adaptive Synthetic Characters for Military Training Simulations

Volkan Ustun, Rajay Kumar, Seyed Sajjadi, Adam Reilly, Andrew Miller

20407

Behaviors of the synthetic characters in current military simulations are limited since they are mostly generated by rule-based and reactive computational models with minimal intelligence. Such computational models cannot adapt to reflect the experience of the characters, resulting in brittle intelligence for even the most effective behavior models devised via costly and labor-intensive processes. Observation-based behavior model adaptation that leverages machine learning and the experience of synthetic entities in combination with appropriate prior knowledge can address the issues in the existing computational behavior models to create a better training experience in military training simulations. In this paper, we introduce a framework that aims to create autonomous synthetic characters that can perform coherent sequences of believable behavior while being aware of human trainees and their needs within a training simulation. This framework brings together three mutually complementary components. The first component is a Unity-based simulation environment - the Training Simulation Software (TSS) API - supporting One World Terrain (OWT) models and capable of running and supporting machine learning experiments. The second is a novel multi-agent deep reinforcement learning library that can interface with a variety of simulation environments, and that can additionally utilize a variety of reinforcement learning algorithms. The final component is the Sigma Cognitive Architecture that will augment the behavior models with symbolic and probabilistic reasoning capabilities. We have successfully created proof-of-concept behavior models leveraging this framework on realistic terrain as an essential step towards bringing machine learning into military simulations: (1) in order to improve the quality and complexity of non-player characters in

training simulations; (2) in order to create more realistic and challenging training experiences while reducing the cost and time to develop them; and (3) in order to make simulations less dependent on the availability of human participants.

Training Responses to Cyber Attacks in a Perception-Based Campaign Model

Charles Burdick, Deepinder Sidhu
20444

Cyber training is typically conducted in exercises employing cyber ranges dedicated to them and trainees get few iterations of an attack scenario. At the same time, most campaign models simply allow an analyst to "twist a knob" to dial in a cyber effect, e.g. reduced lethality. But the opportunity exists to both obtain better cyber effects data by collecting in low-cost training exercises and linking it with a GFE perception-based model that was used by JFCOM J9 to conduct simulation-supported wargaming, while JFCOM existed.

All information transfers in the J9 Joint Analysis System (JAS) model occur over simulated networks and a network disruption causes the delay or loss of specific information, which impacts subsequent operations. For J9 wargames, JAS was paused, and human decisions-makers replaced selected simulation agents. The humans read the same status reports as the agents, observed the map-based perceived Common Operational Picture (COP), and then made the best decisions they could, based on the potentially late/distorted information available.

To better determine how long cyber disruptions lasts, the authors propose employing network emulations using virtual hardware now becoming available and using them to create low-cost, full fidelity network digital twins of operational networks. These emulated networks can reside in small footprint equipment and the actions of Blue Defenders and Red cyber-attack Teams using them for home station training would reflect credible times and success rates to defend/attack typical operational networks. Meanwhile, in the wargame, humans can employ alternative communications paths and conduct other measures (if they exist), to recover as quickly as possible from the attacks. The combination significantly improves our understanding of the value of cyber training while responding to simultaneous kinetic attacks on our C2 infrastructure and nonkinetic EW and deception impacts. This combination should greatly improve our training to defend our C4ISR systems

Implementation of Autonomous Vehicles within a Multimodal Traffic Simulation Framework

Vijay Kalivarapu, Eliot Winer
20455

In 2014, companies had invested about $167 million into Autonomous Vehicle (AV) technologies. By 2019, these investments totaled more than $100 billion. The Pentagon's 2020 fiscal year budget proposal included $3.7 billion for research and development of unmanned and autonomous technologies. Studies show that 52% of battlefield casualties occur when soldiers deliver food and other supplies in combat zones, and hence was theorized that the use of AVs could substantially mitigate such risks and save lives. However, AVs must be tested in a multitude of scenarios before they are practically viable for military and civilian applications. Physical AV data for testing are generally unavailable from commercial or military entities due to proprietary or security concerns. This makes simulations a feasible alternative to study them. However, creating AV simulations with the fidelity, scalability, and customization come with a number of research questions such as: how can AVs be trained for autonomous driving?, how can communication be established between different traffic management subsystems? and how can multiplayer collaboration be achieved?

A three-component visualization framework was developed to address the above challenges. First, multiple virtual vehicles were trained using machine learning techniques to autonomously drive within a specific road intersection scenario. Second, these virtual AVs were introduced to physical agents such as cars and bike riders. Third, the driving states of the physical agents and the AVs were synchronized using a client-server architecture with a traffic simulator that probabilistically generated vehicle and pedestrian traffic. The AVs and the physical agents appear as entities within the traffic simulator to which the generated traffic computes responses and are network synchronized to collectively form a multimodal traffic simulation system. Results from implementing and testing this framework in multiple scenarios show that properly trained AVs can serve as a proof-of-concept validation for developing military and civilian applications.

TRAINING

BEST PAPER

Neuro-optimization for accelerated learning pace and elevated comprehension: Military Applications

JJ Walcutt, Walt Yates, Dhiraj Jeyanandarajan
20399

Advances in technology, digital connectivity, and doctrine to embrace all domain warfare will continue to increase the complexity of tasks for warfighters at every echelon. The ability of servicemembers to train faster and within more cognitively demanding battlespaces is equally as important as maintaining a technological advantage. Cognitive optimization, however, is hindered by natural human limits to knowledge and skill acquisition. The effects of overloading the brain with data and stress has repeatedly been shown to lead to constrained information intake, reduced focus and understanding, and at worst, Post Traumatic Stress Disorder (PTSD). The imperative to optimize the capability of the warfighters creates the necessity of conducting training within a human-technology hybrid system, a requirement.

Substantial research has been conducted in the area of personalized learning informed by both performance and neuro-physiological data. The data collected has been largely unreliable, inexact, and delayed, leading to extensive lab-based studies but fewer successful applied hybrid training programs. As both the technology validity and reliability have improved over the past 20 years, the data we can extract has the potential to not only optimize the way we do training but raise the cognitive advantage across our forces. This paper presents data from 3 experiments that show: (1) the most reliable combinations of EEG features for measuring cognitive load across a variety of tasks; (2) changes in EEG measured cognitive load when learning new material; and (3) real time changes in how audiovisual complexity lead to reliable changes in cognitive load.

The war of cognition requires our servicemembers to train faster, better, and cheaper in order to maintain our advantage but we must first overcome the limits of the human mind to ensure that we can optimize all warfighters while also protecting the human mind from harm due to overuse, data overload, and stress.

Performance Measurement Applications and Associated Data Requirements for Simulation-Based Training

Jeffrey Beaubien, Michael Tolland, Jared Freeman
20206

There are numerous applications of human performance measurement during training. These include supporting the post-training debriefing; estimating rates of skill decay for use in scheduling refresher training; making data science-based simulator acquisition decisions, and; quantifying training Return on Investment. While much has been written about human performance measurement in the abstract (Beaubien et al., 2017; Dwyer et al., 2001; Rosen et al, 2008), researchers have yet to formally specify the critical High Level Architecture (HLA) or Distributed Interactive Simulation (DIS) data elements that are required to support these specific applications in practice. For example, if the goal is to facilitate a single post-training debriefing, one only needs to record the learners' performance score. If the goal is to compute skill decay rates, one must also collect each learner's unique identifier, each training trial's unique identifier, and the unique timestamp. Finally, if the goal is to make data-science based simulator acquisition or ROI decisions, one must also collect metadata about each simulation platform's fidelity cues and costs. The purpose of this paper is to specify the critical data elements that are required to support these three applications. While some of the data elements are common across all three applications; others are application-specific. Similarly, some are transmitted across the HLA (or DIS) data bus, while others are accessed via other means. Finally, some are specific to Human Performance Measurement Language (HPML), while others generalize to the Experience API (xAPI). The paper will conclude with best practices and lessons learned for researchers, developers, and engineers about how to systematically collect, annotate, aggregate, archive, model, and visualize human performance data during training to support these three applications.

Quantifying Learner Expertise Using Unobtrusive Measures of Cognitive Load During Training

Jeffrey Beaubien, Rachel Elkin, David Kessler, Todd Chang, Nathaniel Damaghi , John Feeney, William DePriest
20224

The construct of cognitive load (CL) is rooted in the dual-process theory of decision-making, which postulates two distinct cognitive processes that operate largely, but not completely, in parallel (Evans, 2003; Evans & Stanovich, 2013). One of these processes, "Type 1," is extremely fast, makes minimal demands on working memory, and operates by associatively comparing the current situation to one's corpus of accumulated prior experiences from long-term memory. Type 1 decision skills are consistent with the recognition-primed decision-making (RPD) approach used by domain experts. By comparison, "Type 2" decision processes involve explicit calculations and conscious deliberation, thereby placing heavy demands on working memory. Type 2 decision skills are consistent with the slow and effortful decision making approach used by domain novices (Kahneman & Klein, 2009). The purpose of the current study was to unobtrusively measure the CL of physicians using wireless, commercial off-the-shelf (COTS) neurophysiological monitors. The participants included a mixed sample of Pediatric Emergency Medicine (EM) physicians (6 novices, 6 experts) who performed four different Virtual Reality (VR) training scenarios (2 clinical scenarios x 2 levels of difficulty). After each scenario, the participants completed a self-reported measure of their mental workload using the NASA-TLX (Hart & Staveland, 1988). The unobtrusive CL measures were significantly correlated with the self-reported mental workload scores. A linear mixed model (LMM) revealed a significant main effect of expertise level (experts had lower CL than novices), as well as a significant expertise-by-clinical scenario interaction. Additional results and implications are presented. This paper concludes with a series of practical recommendations for researchers who wish to use Head Mounted Display (HMD)-based VR training systems while simultaneously using with electroencephalogram (EEG)-based measures of CL.

Precision Learning at CSCS: Teaching to the Student, Not Just the Class

Janet Spruill, Lloyd Kleinman, Jeffrey Beaubien
20227

The U.S. Navy continues to make advances in data-rich live, virtual, and constructive (LVC) training environments that provide the ability to harness human performance data and apply machine learning (ML) and artificial intelligence (AI) to realize gains in mission performance and readiness. Additional advances in instructional methods and data science, when combined with this ability to understand and act on human performance data, provide a foundation for creating precision learning environments.

During live training, instructors offer hints and guidance in response to the students' verbal and nonverbal cues. They also modify the sequence of training content and direct the student to additional practice time or skill remediation activities, as required. Precision learning technologies aim to emulate, not replace, this guidance in order to provide an optimal, tailored learning experience for every student. These technologies rely on real-time measures of learner performance, and use algorithms that determine precisely what the learner knows in order to recommend what learning experiences should occur next. By tailoring the sequence, difficulty, and type of learning content to the needs of each individual student, precision learning approaches can accelerate time to proficiency. Further, when critical data and performance indicators are captured and catalogued, they can be used in individual and team assessments across domains, in after action reviews, and as a means of tracking performance and proficiency over time.

This paper will detail the precision learning concepts and technologies recently adopted by the US Navy's Center for Surface Combat Systems (CSCS). The authors will describe methods used to create the first implementation of an environment that enhances existing training content; deliver an optimized learning path, and; help instructors know exactly how each student is performing. Specific guidelines and lessons learned will be shared so that readers can implement these approaches in their own organizations.

Digital firing, a new way of training

Joachim Laguarda, Kevin Ly Van, Benoit Houssu
20245

Present small-arms training solutions still have limitations and drawbacks. Often based on laser technology, instrumented screens and closed rooms are required which limit the operational capabilities. The calibration of such systems is also often complicated, involving time consuming adjustment. In case of live training systems in large open areas, a standard laser solution shows occultation and accuracy problems (e.g. partitions, leaves…) and requires instrumentation of all potential targets.

A new solution addressing all these issues has been developed. Laser technology got substituted for a standard camera. Calibration, shooting direction and firing result are digitally determined through patented algorithms which provide a complete analysis of the shooting and associated performance. Ballistics models take into account ammunitions, gun parameters and meteorological conditions. There is no synchronisation issue or limitation of the number of weapons and players involved in a concurrent exercise. Targets can either be fixed targets, virtual entities displayed on projection screens or even mobile entities in a real environment, indoor or outdoor. There is no need for a digital twin of the environment.

Each individual trainee analysis report is transferred to the Excon station for further debriefing. AI is then used to go deeper in the analysis (target recognition, gunner attitude, gun handling, aiming process…) and alleviate the instructors' workload by providing valuable information. In case of operational scenario involving several trainees (blue and red), AI will also be used to provide to the instructor an evaluation of the collective team behaviour.

The paper will describe the technical approach with its main principles and experimentation results conducted with the French and German Forces. The next steps will then be presented.

''You have control, AI has control'' the 2030 Flying Instructor?

Helen Gardiner
20280

In as little as 10 years, Combat aircrew will manage a complex array of airborne weapons systems, often operated remotely or even autonomously that are optimised to take all but the most complex or lethal decision making tasks away from the operator. Systems management, analytical problem solving and timely, effective, decision making will be the key competences of the air minded war fighter, be they controlling weapons systems from the air, on the ground or from space.

So what of the flying instructor?

As a former RAF fast jet pilot and flying instructor, the author has appreciated at first hand the importance of the individual being taught handling skills, tactical knowledge and airborne proficiency based on the long held fundamentals of 'airmanship'.

With the ability for future platforms to fly autonomously, will the traditional skills of a 'pilot instructor' become obsolete? As performance focuses more on mental agility, flexibility, adaptability and speed of mental processing power, what will be the role of the future flying instructor? Can Artificial Intelligence provide the means for developing these key aircrew cognitive skills?

Drawing upon valuable feedback and insight from the current generation of aircrew within the authors training services, this paper will explore the aspects of human performance relevant to future combat aircrew and ask whether Artificial Intelligence and new training technologies can provide the solution to their future training needs. It will consider how excellence in aircrew performance can be achieved and enable a deeper understanding of the benefits and limitations of both human and technological training capabilities.

Finally, if Artificial Intelligent Instruction becomes common place, the paper will explore the challenges this may create in maintaining a minimum viable number of real humans who are suitably qualified and experienced.

Mapping e-Learning Preparation to Training Objectives in a Multinational Exercise: A Q-Matrix Approach

Biljana Presnall, Ryan Baker
20281

Multinational training exercises are an important part of developing joint preparedness. Increasingly, participants in multinational training exercises are provided with e-Learning training prior to and during the exercise. Understanding whether materials are well-aligned to the needs of participants during the training exercise helps us to understand whether the materials will ultimately be beneficial in the settings the training exercises are preparing forces for: planning and conduct of a combined and joint Crisis Response Operation (CRO), using Standing Operating Procedures (SOP), within a NATO-led operation.

However, methods for establishing the alignment of e-Learning to a training exercise have thus far largely been based on the judgment of domain experts. Domain experts do not always perfectly understand where their training materials are having their greatest impacts on performance, particularly for highly complex domains. We propose a new approach, based directly on trainee data. Specifically, we analyze the alignment between e-Learning and training by analyzing data on how specific trainees use the e-Learning, and the performance of the trainees' units on specific objectives.

We frame this measure of alignment as a Q-Matrix, a representation of the links between two sets of constructs. Q-Matrices are commonly used in cognitive diagnostic testing and intelligent tutoring systems to represent the links between latent student skills and specific performance items. In this case, we use Q-Matrices to represent the connections between the use of

specific e-Learning modules and training unit performance on specific objectives. We propose a concrete heuristic for this mapping procedure based on time-on-task and performance ratings. We apply this heuristic to study the applicability of a set of three e-Learning training modules to trainee performance at conducting current operations and both mid-term and long-range planning, analyzing this question within the context of data from a multinational training exercise CJSE19 with participation from 12 countries.

Adaptive Blended Learning Experience (ABLE)

Jody Barto, Tarah Daly, Amy Lafleur, Natalie Steinhauser
20287

Across 87 formal learning centers, the United States Marine Corps Training Command is challenged with training large numbers of Marines with limited instructors and time available. Instructors need strategies and tools to support and enhance the student learning experience while optimizing their use of time and resources. Furthermore, due to a need to prepare Marines for tomorrow's increasingly uncertain, complex, and decentralized operating environment, MajGen Mullen, Commanding General of Training and Education Command, has called for an institution-wide shift from passive, instructor-focused training towards an active, student-centered learning model. Courses need to be designed and delivered in a way that is engaging, interactive, personalized, and that increases efficiencies for instructor time. The Adaptive Blended Learning Experience (ABLE) project addresses these challenges and extends the research and development for the areas of adaptive learning and blended learning designs.

The purpose of the ABLE effort is to develop a model to deliver Military Occupational Specialty (MOS) specific training content in a self-paced, adaptive format that enhances student learning and creates efficiencies for instructor time. Two Marine Corps Intelligence School courses teaching Center of Gravity (COG) Analysis were selected as the testbeds for this project: Tactical Intelligence Officer Course (TIOC; a fully resident course) and MAGTF Intelligence Analyst Course (MIAC; includes a non-resident portion). An adaptive Moodle (an LMS) lesson was designed to enable self-paced learning and personalized remediation of COG Analysis basic concepts so subsequent instructor-led classroom time is devoted optimally for advanced practical application exercises. An experimental study design is being applied to measure learning effectiveness and time efficiency associated with the ABLE intervention of the COG Analysis module in comparison to current practice. The outcomes of this effort contribute to developing a framework for effective, adaptive, blended learning course designs throughout Training Command, generalizable to other training and educational settings.

A Qualitative Study on Behavioral Markers of Team Cohesion and Efficacy to inform the Army's Synthetic Training Environment

Sean Normand, Joan Johnston
20289

The U.S. Army's synthetic training environment (STE) will combine live, virtual, and constructive technologies to deliver a comprehensive collective, multi-echelon training experience to form agile, adaptive teams. To optimize training effectiveness, the STE will automate the collection and assessment of team processes (e.g., cohesion) and performance outcomes (e.g., mission accomplishment) and use the results in automated after action reviews. In their recent meta-analysis Sottilare et al. (2017) demonstrated team cohesion, collective efficacy, and communication are significant antecedents of effective team performance, however, they determined the diagnostic effectiveness of such self-report measures as cohesion are limited (e.g., judgment errors and social desirability bias) due to the dynamic emergence of team effectiveness during training. Therefore, they provided a detailed analysis of potential behavioral markers of cohesion, efficacy, trust, etc., which they proposed could improve team measurement under dynamic conditions. Toward this end, in this paper, we report on a qualitative study in which we identified and collected behavioral markers of cohesion and efficacy communications in conventional and special operations combat fire teams in training situations. Pattern matching methods were developed with subject matter experts (SMEs) to identify the markers, and then the SMEs applied the assessments to video and audio recordings of 64 Soldiers (21 fire teams) performing training scenarios. We found that patterns of team cohesion and efficacy can be systematically observed and assessed during dynamic training situations. We also identify how these patterns could relate to mission outcomes, and then discuss lessons learned on the technical challenges, such as speech recognition, that need to be addressed to inform the STE.

MILES Emitter Unit Integration for Area Coverage Weaponry

Samantha Markowitz, Brendan O'Neil, Edward Cole, Matthew Tomik
20297

Incorporation of the Multiple Integrated Laser Engagement System (MILES) into Warfighter training can result in enhanced learning and performance over non-MILES training. MILES is designed to mimic active battle during Force on Force training by simulating weapon lethality and providing real-time casualty assessment. However, MILES integration for area coverage weaponry is largely nonexistent. This paper outlines the development, challenges, and benefits of incorporating MILES into such weaponry. Among these challenges are variation in MILES capability between and within training centers, with older hardware being unable to recognize some weapons-specific signals, and how MILES hardware processes received signals. MILES uses a random number roll and causality probability look up table to determine lethality of an encounter, making it difficult to simulate reliable lethality. The development of the Claymore Training Aids, Devices, Simulators, and Simulations (TADSS) system was able to successfully incorporate a MILES Emitter Unit (MEU) to replicate the lethal area coverage of the tactical Claymore through a combination of lasers and LEDs to send MILES signals. A test emitter was developed that permitted modification to the signal emitted by the MEU, power levels, and angles of engagement with MILES equipment. Extensive field testing involving firing the MEU over various distances and orientations at MILES hardware was conducted to verify characterization of the MEU signature. Additional testing showed reliability over a range of environmental and light conditions. The MEU was ultimately able to induce MILES response over the kill area over 80% of the time while accurately replicating Claymore effective range. The methodology and test data obtained during this development can provide a pathway for the creation of future training systems to be integrated with MILES, providing more realistic simulation of weapon lethality for soldiers in training.

A Framework for Action Detection in Virtual Training Simulations using Synthetic Training Data

Andrew Feng, Andrew Gordon
20302

In virtual military training, tracking and evaluating trainee behavior throughout a simulation exercise help address the specific training needs, improve the realism of simulations, and customize the training experience. While it is straightforward to parse the event log of a simulation to identify atomic behaviors such as unit movements or attacks, it remains difficult to fuse these events into higher-level actions that better characterize trainees' intentions and tactics. For example, if each unit is controlled by an individual trainee, how should the movement information from all units be aggregated to determine what formation the group is moving in? Similarly, how can all of the information from nearby terrain environments be combined with kinetic actions to determine whether the trainees are executing an ambush attack, or is simply engaging the enemy group? While an experienced human observer-controller can quickly assess the battle map to provide an appropriate interpretation for such events, it remains a challenging task for computers to automatically detect such high-level behaviors when performed by human trainees.

In this work, we proposed a machine-learning (ML) framework for recognizing tactical events in virtual training environments. In our approach, unit movements, surrounding environments, and other atomic events are represented as a 2D image, allowing us to solve the action detection problem as image classification and video temporal segmentation tasks. In order to bootstrap ML models for these tasks, we utilize synthetic training data to procedurally generate a large amount of annotated data. We demonstrate the effectiveness of this framework in the context of a virtual military training prototype, detecting troop formations and other tactical events such as ambush and patrolling.

Virtual Leadership Simulator – The Missing Gap in Soft Skills Training

Andrew Clayton, Carrie Straub
20325

The rapid improvement of virtual, augmented, and mixed reality simulators has dramatically changed how the Air Force trains Airmen in their specific technical skill sets. Some examples are pilot training, air operations training, security forces training, battlefield training, vehicle training, and medical training to name a few. However, the use of AR/VR simulations for educational and developmental purposes for soft skills is far less developed in the military. The lack of attention and effort to develop a virtual simulator that can allow military personnel to develop leadership or soft skills, through a mixed reality or virtual simulation has proliferated a growing skills gap with consequential impact on the personnel and industry. Like technical skills training, leadership training also requires authentic, immersive, and real-world scenarios in a safe, repeatable environment. For the past three years, Air University has explored, developed, and initiated a project to fill in the leadership development skills gap using a mixed reality simulator known as a virtual leadership simulator (VLS). Because human interaction can be the most difficult to predict, the VLS uses both artificial intelligence (AI) and live actors (simulation specialists) to deliver powerful simulations that mimic the most challenging situations that military personnel will face in their role as leaders. Now, the development of

leadership or soft skills can be practiced in the same manner the military trains personnel for hard skills training. Expanding the use of AR/VR simulations into the field of leadership development is an innovative approach shifting the paradigm from not just a technical skill set need but the need for leadership development as well. This paper outlines the 3-year project, its results, the educational learning theories behind the VLS, and why the VLS has been so effective in revolutionizing how the military uses virtual simulators.

Trainer Situational Awareness Methods in Virtual Reality: A Scoping Review

Kaitlyn Ouverson, Eliot Winer

20336

This year, the US Navy budget for Training and Education increased by $73.9 million to accommodate additional flight training and simulators. These simulators are essential for preparing trainees for scenarios that are rare, dangerous, complex, and expensive to stage in reality. While training simulations have historically run in costly and immobile “big box” simulators, these simulations can now be deployed using consumer-grade immersive virtual reality (VR) head-mounted displays (HMDs). For example, Navy maintenance Airmen use VR HMDs to train on the C-130 due to time and money savings over live training, without loss of training effectiveness. However, one concern when using an HMD for training is communication between the trainer and trainee. Typically, trainers observe a trainee’s progress in a simulation from a monitor that provides a window into the virtual environment. This window is missing artifacts, such as stereo depth, that may make contextualizing a trainee’s actions difficult. More recently, the method of using multiple HMDs so a trainer may be present in the environment has been introduced. Although this allows better communication between trainer and trainee, interactions between avatars may be difficult to interpret, and awareness of trainee interaction with items outside the simulation is obscured. A scoping literature review was performed to address these issues, exploring the domains of asymmetric VR, substitutional reality, and self-adaptive training systems to incorporate human trainers into the virtual scene as active participants and trainee guides. The authors evaluate current innovations in VR collaboration techniques for their impact on trainer-trainee communication in VR simulations to guide industry and interservice training professionals. Results show that for each of the current VR collaboration techniques, the trainer situational awareness benefits and deficits must be aligned to the training task.

Air Force Orbital Mechanics & Space Operations Training In Virtual Reality

Matthew Fahnestock

20341

With the establishment of the U.S. Space Force (USSF), it is imperative Airmen understand orbital mechanics and space operations. Concepts like Hohmann transfers and Rendezvous and Proximity Operations (RPO) for spacecraft orbital maneuvers can be time-consuming to teach and difficult to comprehend. Current teaching practices involve extensive textbook descriptions, whiteboard sketches, and two-dimensional (2D) animations. This research paper suggests Virtual Reality (VR) technology could improve comprehension and retention of orbital mechanics and space operations concepts. The paper begins with an overview of current threats to U.S. space superiority, as well as an outline of the latest U.S. military doctrine on space. This provides a background for the establishment of the USSF and the importance of having Airmen who are properly trained to operate spacecraft in the space domain. Next is a description of teaching basic orbital mechanics concepts using traditional “textbook” methods, followed by an explanation of what VR is and how it can be used for learning. This includes research on how people experience and comprehend VR, the latest VR technologies being developed, and some of the newest theories on learning including gamification and connectivism. Finally, the paper proposes potential methods for modernizing current orbital mechanics and space operations teaching practices by introducing VR technology combined with updated learning theories. The space domain is more congested and contested than ever, and VR is just the tool to prepare the next generation of space operators for this fast-paced and continually evolving environment.

Mission Training through Distributed Simulation for Joint and Combined Air Operations

Arjan Lemmers, Richard Hemmings, Clark Swindell

20344

A range of factors (reduction of range space, airspace limitations, weapon systems availability, lack of target simulation capabilities, hostile capability monitoring) are driving NATO to a transition towards distributed synthetic enabled training. To help achieve this transition, NATO Science and Technology Organisation (STO) task group MSG-165 is established, tasked to execute Incremental Implementation of Mission Training through Distributed Simulation (MTDS) for Joint and Combined Air Operations.

The development of MTDS capabilities is not limited to the work of MSG-165; indeed, it is one of NATO’s Smart Defence Initiatives, sponsored by the United States, and therefore has good visibility on various levels, but sadly still fails to achieve the necessary progress. Whilst several challenges remain, the work undertaken thus far by the group has offered solutions to other existing NATO synthetic training issues. These are captured in documents and include:

Establishment of common Air training objectives, helping to define Alliance training requirements, helping to align appropriate training media.

Formulation of Reference Architecture principles, providing a foundation for Joint MTDS capability employment.

Set-up of a MTDS capability validation exercise, called SPARTAN EVENT 20-9 (SE 20-9). SE 20-9, as a modification of the SPARTAN WARRIOR scenario, is a multilateral engagement opportunity coordinated by the USAFE Warrior Preparation Center (WPC) to provide Coalition partners persistent connectivity over the Combined Federated Battle Laboratories (CFBL) Network at NATO Secret classification level for daily, coalition focused, unit-led training.

The development of an MSG-165 vision of how MTDS could be employed to support NATO Air operational training. The methodology employed in developing this vision shows wider utility, and the potential for use in helping other components define their own future training visions.

This paper will highlight the achievements towards a common NATO Joint MTDS environment and sketch the following steps to mature this upcoming important training capability.

Capture-the-Flag: Paradigm Utility for Enhancing Red Team Readiness

Tashara Cooper, Johnathan Harris

20345

U.S. Department of Defense (DoD) Red Teams face a number of challenges relative to training and maintaining readiness, and the persistence of these challenges place DoD cybersecurity strategic goals and objectives at risk. Senior leaders depend on adversarial assessment to mitigate risks to weapons systems, operational networks, and critical data infrastructures. Although adversarial assessment is a team function, cyber test and evaluation (T&E) Red Teams often train as individuals. Some challenges to training are due to availability of people to train (personnel), scheduling time to train (on-the-job) and opportunities for time to practice (on one’s own) . Ideally, training would afford cyber T&E Red Teams with the opportunity to engage in realistic training at the team-level beyond the classroom and sterile hands-on lab environment. Proposed is an offensive focused Capture-the-Flag game-based training paradigm. This training paradigm attempts to replicate real world systems or subsystems to practice both offensive and defensive cyber missions. By emulating the current threat landscape through offensive and defensive cyber missions, it supports red teams in maintaining personnel attributes required to remain agile in assessing changing tactics, techniques, and procedures of cyber-based adversarial attacks.

Data Visualization to Improve Evaluation for Live Training

Eric Sikorski, Gregory Goodwin, Jennifer Murphy, Grace Teo

20360

A challenge of conducting an effective after action review (AAR) for live training is relying on the recall of human observers. Expert trainers, leaders, and trainees are known to have fallible and incomplete memories of even recent events. The most common record of live training tends to be video captured from multiple cameras strategically located throughout the range. A 30 minute training event may generate several hours of video footage across all of these cameras. However, video footage does not easily yield quantifiable performance metrics to support evaluation or AAR. We recently collected audio files from Army squads executing battle drill 2A (i.e. squad attack) on a live-fire range. These audio files were processed to extract voice communications and rates of fire for fire team members laying down suppressive fire. Additionally, we collected hit data from targets. Using these non-video data sources we were able create timelines of the exercise to show how effectively the team members communicated and managed their volume of fire over time and space. We were also able to overlay doctrinal rates of fire so that they could directly compare their performance to those rates. Using the overlay, we could also show probabilities of hits and kills and the effectiveness of their fire at suppressing the targets. This type of visualization provides a succinct, quantifiable summary of squad performance that can be used for evaluation and AAR purposes and may offer significant advantages over video-based assessments for live training.

Virtual reality for transportation incident management training of first respondents in remote areas

Bruno Emond

20376

Training volunteer firefighters in remote areas on major transport incidents, such as train derailments containing dangerous goods, is challenging on many levels. Even though these incidents are rare, their consequences can be damaging for local communities, the environment, and the transportation supply chain. A report (Transport Canada, 2015) indicates that firefighters are not adequately trained for large scale train incidents involving dangerous goods, that they do not have the necessary skills to use specialized equipment, and that small and remote communities have limited capacities to respond to these incidents. A main issue is that the training expertise is often located in urban areas, which suggests that a technology-based approach could offer an essential element to increase first respondents' awareness, operation, and command knowledge and skills. In this respect, Virtual Reality (VR) offers a potential alternative to training methods such as web-based e-learning solutions, allowing for realistic and safe simulation of a wide range of dangerous fire scenarios. In addition, the capability to bring multiusers into a shared VR space enables team training, and remote instructor feedback and support. The paper reports on our progress in the development of a VR training environment where a novice first respondent is acquiring situational awareness of a train derailment while interacting with an intelligent tutoring system. The system is being developed with off-the-shelf and open source components including Oculus Rift S, Unity, and the Generalized Intelligent Framework for Tutoring (GIFT) (ARL-HRED, 2012). The paper also presents how the different elements of the adaptive instructional system are implemented in the GIFT architecture including the user interface, domain knowledge, learner, and pedagogical models.

Transport Canada. (2015). Emergency Response Task Force Second Quarterly Report and Recommendations. Retrieved February 24, 2020, from https://www.tc.gc.ca/media/documents/tdg-eng/ERTF_SECOND_QUARTERLY_REPORT_ENG-A.pdf

ARL-HRED. (2012). Generalized Intelligent Framework for Tutoring (GIFT). Retrieved February 24, 2020, from https://www.gifttutoring.org

Defense Workforce Readiness Pipeline

JJ Walcutt

20396

The National Defense Strategy (2018) notes significant concern about the workforce pipeline of the future. As technology matures and becomes more affordable for adversaries of any size, our global advantage begins to erode. It means the currency of tomorrow will not only include our financial and technological capabilities but also our ability to ensure a deep bench of qualified civilian and military workers. In response, a significant number of programs have been developed from youth outreach competitions like CyberPatriot to collegiate critical language internships to sponsorship of university and innovation research. At every level, key opportunities exist, however the strategic connections across these programs are lacking or non-existent.

Accordingly, the National Defense Industry Association (NDIA) has identified the workforce readiness pipeline issue as a key priority and is taking action to consider solutions that may help improve the strategic planning but also the network of opportunities across the defense industry. The pipeline of the future will need to marry the goals of the Defense Department with the capabilities available across the workforce and those needing to be developed. It will use a digital backbone to capture, connect, and match skilled workers across all ages, experience, and education. Most notably this connectivity will allow for two key opportunities. First, it will support learners of all ages to progress through the pipeline more efficiently by personalizing planning and recommending a series of training experiences. Second, it will help identify individuals most closely aligned to future skilled jobs, assess the additional skills needed to match, and then train those remaining components. In other words, training efficiency will be substantially enhanced to meet the constantly evolving defense workforce needs. This paper will explore current issues, goals, and programs available then provide recommendations to organizing strategic programs who can oversee these enhancements to improve planning.

Same Injury, Different Outcome? Investigating Hesitation while Treating Female Casualties

Mark Mazzeo, William Pike, Jessica Bell, Robert Thomson

20410

Men and women serving in Tier One or Tier Two battlefield caregiver roles (i.e., buddy-aid, Combat Lifesaver) may be reluctant to perform certain procedures on a wounded female. Anecdotal observations (Mazzeo et al., 2018) support this claim. A more rigorous, quantitative analysis is being conducted at the United States Military Academy at West Point. Participants will be measured on reaction time, time on task, and accuracy (collectively representing overall performance) while treating both male and female patient simulators for two gunshot entry wounds in the upper torso (within-subjects design). Treatment will require participants to expose the injury sites; for the female simulator this will require participants to remove a sports bra. Analysis will focus on whether reaction time, time on task, or accuracy increases or decreases significantly moving from a male to a female patient simulator. Two families of hypotheses will be explored: overall performance, and participant gender-specific performance (i.e., male participant treating male patient, female participant treating male patient, male participant treating female patient, and female participant treating female patient). This study serves an important step in determining whether the original anecdotal observations can be verified quantitatively, and whether differences in performance when rendering trauma care is significant across genders. This paper will also discuss a model for Cadet-led experiments with mentoring from senior research and development professionals.

References:
Mazzeo, M., et al. (2018). Development and assessment of a human patient simulator gender retrofit kit. Proceedings of the 2018 Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC), Orlando, FL.

Maintenance Training in a Digital Twin with Machine Learning

Jeremiah Folsom-Kovarik

20436

The US military is in need of technical personnel capable of diagnosing and resolving operational system issues as part of their maintenance duties. Schoolhouse training needs to deliver both familiarity with fundamental principles and readiness to maintain specific devices. The usefulness of the training after deployment is challenged by skill decay, systems updates, and idiosyncratic systems that behave differently from a general model because of usage or wear.

A digital twin provides a simulation that models one individual device, rather than a general model of an idealized device. The increasing use of digital twins, especially in industrial applications, provides a wealth of data that can create training specific to one device. Training with a digital twin can create a high-fidelity experience to accelerate learning, minimize skill decay, improve transfer of skills from the schoolhouse to the operational platform, and support on-the-job training once deployed.

We address two of the challenges in using digital twins for training. First, we describe an approach to train underlying principles with a model of physical system performance across different systems (e.g., propulsion, sonar, radar, fire control), subsystems (e.g., mechanical, electrical) and components (e.g., valves, actuators). Second, we describe how to author training with the model that enables focusing on key parts of a process, accepting learner input, predicting device outputs, and assessing learner performance for feedback to learners or instructors.

The approach to turn data into training relies on machine learning from the behavior of a single device. We demonstrate the accuracy of our machine learning with data from a commercial jet engine. We show that our approach predicts how an individual engine will respond to wear and maintenance. As a result, the digital twin can present a number of training scenarios with automated instructional feedback.

Considerations for Adapting Training Technologies for Manned-Unmanned Teaming Operations

John Killilea, Emily Anania, Beth Atkinson, James Pharmer, Tawne Frick

20447

The proliferation of automation within military contexts is a driving force in the effort to enhance and expand current manned-unmanned teaming (MUM-T) programs and policies. However, the shift from manned teaming to a collaboration between manned, unmanned, and automated and autonomous entities will also require a shift in the knowledge skills and attitudes (KSAs) trained for these teams. This will also necessitate a paradigm shift in content, as well as delivery. Fortunately, new training technologies can be implemented in order to support this changing terrain.

Overall, three broad areas of changing dynamics for MUM-T are: intuitive communication with automated technologies, trust in these technologies, and workload balance between manned and unmanned counterparts. Communication will change vastly when operators are communicating with unmanned, and automated or autonomous entities. Appropriate calibration of trust is also a large barrier to seamless MUM-T coordination, given that new technologies involving automation suffer from operators under or over-trusting

them. In addition, the rapidly changing abilities of technologies as well as the needs of the warfighter will require that operators be able to manage their own workload and take on or shed tasks when appropriate.

Also crucial is the role of these KSAs in defining the training technologies being utilized. It is likely that moving forward, the challenges presented can be partially mitigated through unique training technology solutions such as synthetic crew members, designing unmanned team members for appropriate trust calibration, and technology aids for proper tasking allocation. The current paper will discuss these three broad areas, the KSAs associated with each, and the prospect of currently-in-development technologies to support the training of these new and changing KSA needs. With this knowledge, practitioners will be able to identify MUM-T training barriers within their own efforts, as well as successfully determine effective training solutions focused on those challenges.

Visualizing The Logistics Dimension With Map-Based Simulations

Michael Hugos, Dennis Duke
20488

Designers of tactical and skills training simulations are understandably reluctant to slow the pace of user interactions in those simulations with complicated rules and calculations to address logistics that support the activities occurring in those simulations. Tactical and training simulations therefore handle logistics only in the abstract. Yet, after the skill and bravery of the troops, logistics is perhaps the next most critical factor in the success of any mission.

Our paper will show how an accurate logistics dimension can be added to any tactical or skills training simulation or federation of simulations. A map-based supply chain modeling and simulation application can connect to a federation of other training simulations in a unified training scenario. This enables people to see, understand and manage the supply chains required to support operations happening in other training simulations. It adds a new layer of reality to other simulations, and enables realistic logistics training in a way not previously possible.

In 2019 we successfully completed a subcontract on a DoD proof of concept project demonstrating how to model and simulate supply chains to support events occuring in a federation of simulations comprising a unified training scenario. Based on that work, we show how logistics simulations can complement and enhance other skills training simulations and also provide effective training for logistics personnel.

Our paper will present a conceptual design for the user interface and technical architecture used to connect a supply chain logistics simulation with a federation of other simulations in a real-time training scenario.Tactical and skills training simulations can illustrate interesting approaches and techniques, but the logistics required to support them is not tested or explored a rigorous manner. This can now be done by connecting logistics simulations to any tactical or skills training simulation or group of simulations.

Designing Serious Games to Train Medical Team Skills

Ashley McDermott, Peter Weyhrauch, James Niehaus
20496

More access to effective medical team training across the DoD can significantly improve patient outcomes and save lives (Hughes et al., 2016). The DoD and medical communities need implementations of team training protocols that do not require extensive time and personnel commitments. Serious games have lower barriers to enable training because they are highly deployable, are available on-demand, and do not require training staff. This paper reports on the process of implementing team skills training within a single-player serious game. In this paper, we present the process of defining what each of these skills entails, defining the mechanics for how to translate the skills into a game environment, and developing a game that captures these skills. Based on a literature review and interviews with experts, we identified three key team skills that would be our focus for implementation. Once the skills were identified, further work interviewing experts and researching how these skills were measured guided our game design. We encountered several challenges, including identifying appropriate scenarios, choosing appropriate fidelities for the game, and designing a communication platform to support conversation between the user and the virtual teammates. Finally, we validated our design through demonstrations to experts. This paper provides a case study for how medical team training translated to a game-based training, which will save time, reduce cost, and increase the people who are able to complete the training.

Moving Beyond Communities of Practice (CoPs) ... Supporting Grassroots Knowledge Sharing

Lara Bove
20498

As automation replaces everyday tasks, the work that people do is changing at an alarmingly rapid pace where “the life-cycle of skills” can be measured in “quarters vs. years” (Saxberg, 2019). The World Economic Forum (2020) predicts that “almost half of the core skills required across all roles will change” in the near future. This problem is not limited to the business sector: it is an issue affecting all sectors of the economy, including government, healthcare, finance, automotive, consumer, aerospace, mining, and information and communication technologies (World Economic Forum, 2018). Workers must be able to navigate this changing field by performing well today while continually developing new skills for the work of tomorrow.

Just as workers must recognize that the skills which helped them to succeed are no longer valuable, organizations must also transform their approaches to skill-building and workforce development. These approaches must:

- Encourage knowledge sharing and less formal training
- support workers learning new skills quickly and on-demand
- encourage workers to share their discoveries and enhanced capabilities with others
- allow workers to self-curate and share learning content

Today’s workforce already has tools which they can use to develop informal training materials to share with their peers. In fact, many of these workers create and share videos on You-Tube to teach strangers how to install windows or fix their refrigerators. If people are able to create and share knowledge in the real world, why not on the job?

While the technology makes it easier to develop and share, it is not enough. Without the cultural underpinnings, this grassroots sharing would happen in isolated pockets. The author provides insights gained from the development of a platform which supports employee-curated/created learning content. These insights inform approaches to operationalize a culture of learning and sharing in the workforce of the Fourth Industrial Revolution.

TUTORIALS

Best Tutorials

A Comprehensive Introduction to Medical Simulation

Roger Smith, Danielle Julian
2006

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 applications that have emerged for COVID response, a brief history, system taxonomies, devices and techniques for representing external and internal anatomy and physiology for medical interventions, the role of team training, criteria for measurement and assessment, specialized military medical applications, and criteria for current simulation accreditation. The tutorial includes constructive models, manikins, part-task trainers, 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 tutorial concludes with a predictive view into the future of the devices and practices as outlined by forward thinkers in the field.

Best Tutorials

Understanding and Applying cmi5 in an xAPI Solution

Andy Johnson, Miguel Hernandez, Art Werkenthin
20032

Developed nearly two decades ago, the Sharable Content Object Reference Model (SCORM) is a set of interoperability standards for packaging and delivering online courses via web-browsers and Learning Management

Systems (LMSs). However, SCORM is not extensible enough to support the myriad of technologies used in modern learning environments, and SCORM does not provide sufficient guidance for capturing robust, interoperable learner performance data. DoD Instruction 1322.26 recommends the Experience Application Programming Interface (xAPI) data specification as the contemporary method for managing learner-performance data, and while xAPI and SCORM can be implemented together, a more modern approach to content packaging and delivery is warranted. The cmi5 specification was created to replicate SCORM functionality, with the intention of replacing SCORM as the de-facto format of online courses and traditional computer-based training. Although the Advanced Distributed Learning (ADL) Initiative created both SCORM and xAPI, they did not create cmi5. The underlying use cases were so similar between cmi5 and xAPI that they simply merged. The cmi5 specification defines a set of rules for how online courses are imported, launched, and tracked using an LMS and xAPI. Technically, cmi5 is an xAPI Profile, which means it inherits all of the characteristics mandated by the xAPI specification, but cmi5 also imposes additional requirements, including interoperability rules for content launch, authentication, session management, reporting, and course structuring. The cmi5 specification also enables the packaging and delivery of distributed learning resources that sit outside of a web-browser (e.g., mobile apps, offline content). The cmi5 specification could play an important role in DoD's modernization, facilitating progress from SCORM-based LMS-centric courseware to a distributed learning "ecosystem" that delivers diverse learning opportunities across a range of federated platforms. This tutorial provides an in-depth understanding of cmi5. It introduces learners to the core concepts of xAPI and cmi5 and of the structure and communication of xAPI data and systems. It describes implementation details, best practices, as well as community activities and resources.

Best Tutorials

Fundamentals of Adaptive Instructional Systems (AISs)

Robert Sottilare, Jeanine DeFalco
20042

The effectiveness of artificially-intelligent adaptive instructional systems (AISs) has highlighted a need in the US military (e.g., Army Synthetic Training Environment) for intelligent, tailored, guided instruction for both individuals and teams. AISs are able to automatically adjust feedback, support, and challenge level of instruction to focus instruction to the specific needs of individual learners and teams. The marketplace for AISs (e.g., intelligent tutoring systems and intelligent mentors) has grown to a point where the IEEE standards community sees merit in developing standards and recommended practices for AIS conceptual modeling, interoperability and evaluation under Project 2247. The prevalence of AI in the IITSEC community highlights the need to understand the basics of AIS design, development, deployment, and evaluation. This tutorial provides a fundamental overview of military needs, emerging standards, conceptual models, adaptive strategies, authoring processes, and the AIS marketplace. We are proposing this tutorial as an introduction to adaptive instructional systems, tools and methods.

Simulation Conceptual Modeling Theory and Use Cases

Jack Borah
2001

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.

An Introduction to Cognitive Systems for Modeling & Simulation

Randolph Jones, Dylan Schmorrow
2007

There are increasing requirements for automated reasoning abilities across the broad spectrum of modeling and simulation, as well as in battlefield information and control systems. Additionally, the cognitive capabilities that have been developed and tested in simulation are migrating to real-world systems. Cognitive systems represent a maturing computational approach to intelligence that can provide robust, scalable, and adaptive decision making. This tutorial provides an introduction to cognitive systems, concentrating on production system computation and high-level design of human-like reasoning systems. We draw examples and comparisons from existing cognitive systems, focusing on the tradeoffs between cognitive and non-cognitive modeling approaches. 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 suggest cognitively based solutions, and they will be better able to assess risks, costs, and benefits of different approaches. 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 be amenable to a cognitive approach.

Securing Real-Time Distributed LVC Simulations at Scale with Data Distribution ServiceTM (DDS)

Robert Proctor, John Breitenbach
20011

Integrating simulation and training systems can be a formidable challenge. Legacy systems often use differing standards for data, voice, and video, while modern architectures demand the use of cloud-based and distributed assets. To top it off, new security requirements now force integrators to suddenly become experts in information assurance. So how do you accelerate integration time to train to meet today's emerging threats? This objective requires training environments that can be quickly assembled and reconfigured from ready-made components. Attend this tutorial to learn how Data Distribution ServiceTM (DDS) can ease integration, while also delivering National Security Agency (NSA) tested security for real-time systems. The Data Distribution ServiceTM (DDS) is a popular open standard managed by the Object Management Group (OMG). DDS is also the connectivity framework that successfully meets the stringent interoperability and real-time requirements of the defense industry, and is currently used in hundreds of deployed systems. DDS seamlessly stitches together legacy 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 can run in a single lab or across multiple sites and DDS is still able to match physics-speed response times. This tutorial gives an introduction to the DDS and DDS Secure standards. You will learn how to use DDS Secure to secure real-world Hardware-In-Loop (HIL) systems that already communicate over DDS to distributed LVC Simulations. The tutorial will further describe how to integrate DDS with existing simulation-based standards, which is an area where DDS can add a large suite of Qualities of Service (QoS) to help tune performance and scalability,while also providing robust security. Finally, the tutorial will highlight recent user experiences with DDS, and offer an overview of deployed systems using DDS in simulators today. This tutorial is intended for all audiences, though some familiarity with the basic principles of distributed computing is recommended.

Introduction to Department of Defense Modeling and Simulation

John Daly, James Coolahan
20014

This tutorial will describe the fundamental technologies, terms and concepts associated with Modeling and Simulation (M&S) and describe M&S development and application in the Department of Defense (DoD). The tutorial will cover various aspects of M&S including key M&S terms and concepts that describe M&S technology, development, and application. It will include: (a) M&S terminology and concepts used in the Department of Defense (DoD); (b) M&S technology, architectures and interoperability protocols and their role in enabling key functions in the DoD; (c) The processes for developing valid representations of: DoD warfighting capabilities, threat capabilities, natural environment, complex systems, cyber, autonomy, artificial intelligence/machine learning, and human and organizational behavior. 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; and the DoD M&S role in enabling key functions of the Department. This tutorial will identify key policies and procedures for DoD M&S, and present the critical role of Verification, Validation and Accreditation (VV&A) in ensuring that models and simulations meet the needs of their users. The tutorial will present the role of M&S Standards in the Defense Standardization Program, its role within the DoD M&S framework, and its impact in DoD M&S use. The tutorial will describe the characteristics and associated challenges of M&S applications within DoD functional areas including: Training, Analysis, Acquisition, Test and Evaluation, Experimentation, Planning, Medical, Mission Engineering, Autonomy, DoD Research and Development/Employment, and Intelligence. The tutorial will also identify accessible DoD M&S information resources and

explain the role of the USD (R&E) DMSCO as the focal point of DoD M&S information, practice, technology, and functional use.

Introduction to HLA

Bjorn Moller, Robert Lutz
20015

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 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 and Air Traffic Control simulation. This tutorial is intended for all audiences; however, some familiarity with basic principles of distributed computing is recommended.

Distributed LVC Event Integration and Execution Process

AuthorNames: Michael O'Connor, Kenneth LeSueur
20017

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 presents a process model for the development of an event. However, the user still has to instantiate the process and develop artifact templates. Based on the experience of the integration and execution of many distributed LVC events, an instantiation of two of the seven DSEEP steps has been developed. This tutorial provides a detailed set of processes, templates, and guidance on how to perform step 5 Integration and Test Simulation Environment and step 6 Execute Simulation steps. The tutorial also describes how the products produced in the first 4 steps are used the subsequent steps. The process covers the integration of simulations and tactical systems to meet the objectives of the LVC event. 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 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 presents a process model for the development of an event. However, the user still has to instantiate the process and develop artifact templates. Based on the experience of the integration and execution of many distributed LVC events, an instantiation of two of the seven DSEEP steps has been developed. This tutorial provides a detailed set of processes, templates, and guidance on how to perform step 5 Integration and Test Simulation Environment and step 6 Execute Simulation steps. The tutorial also describes how the products produced in the first 4 steps are used the subsequent steps. The process covers the integration of simulations and tactical systems to meet the objectives of the LVC event. 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,

An Introduction to RIEDP Concepts for Environmental Data Sharing

Jean-Louis GOUGEAT
20020

This tutorial provides an overview of the fundamental concepts and components of RIEDP (Reuse and Interoperation of Environmental Data and Processes), developed within the Simulation Interoperability Standard Organization (SISO). The focus of RIEDP is on the harmonization of environmental/terrain database generation processes, and the means to exchange such generated data. RIEDP promotes reusability of database generation efforts and fosters interoperability between simulations by providing standardized rules, methods, and semantics for sharing data from key stages of the simulation database generation process. RIEDP leverages existing source data formats commonly used in GIS and simulation applications. RIEDP concepts and components are embodied in two SISO products: the RIEDP Data Model Foundations and the RIEDP Detailed Features Description. The tutorial will highlight key concepts from these RIEDP specifications and will provide an overview of the RIEDP Reference Process Model (RPM), the RIEDP Reference Abstract Data Model (RADM), and how RIEDP uses existing formats and a robust approach (including semantics through attributes and attribution, innovative and efficient use of metadata constructs, data organization on media, and a set of profiles for specific application sub-domains) to share and exchange environmental data.

NATO Simulation Interoperability - Certification, Tools and Standards for Federated Simulation

Bjorn Lofstrand, Reinhard Herzog, Tobias Kuhn, Horst Behner
20021

NATO and partner nations regularly conduct multi-national simulation-based computer-assisted exercises. These exercises can be very large with several participating nations using their own simulation and C2 systems. One of the main challenges is to ensure interoperability between participating systems. To address this problem NATO relies on standards for federated simulation and tools & processes to verify and certify compliance with these standards. This tutorial is focused on providing the wider community with an understanding of how NATO manages and develops standards for Modelling and Simulation. In particular, the tutorial will cover how the NATO Modelling and Simulation Group (NMSG) have worked to develop the NATO Education and Training Network (NETN) Federation Architecture and FOM Design. This standard (NATO STANREC 4800) is an Allied Modelling and Simulation Publication (AMSP-04) that complements and extends other standards for distributed simulation such as HLA and RPR-FOM commonly used when integrating distributed simulations for military training and education. In the tutorial, we will provide in-depth information on these standards and how they are applied to provide NATO partners with the means for delivering systems with a higher level of interoperability. We will also provide information on the NATO Simulation Interoperability Certification process and available NATO tools to support verification, integration and certification. The concepts of Interoperability Capability Badges and Interoperability Requirements will be introduced and their relationship with NATO simulation interoperability certification will be explained in detail.

Building an Education and Training Data Strategy

Jerry Gordon , Brent Smith
20023

Throughout their careers, DoD personnel are educated or trained by numerous organizations, each using their own IT systems and business processes. Typically, these systems are developed and implemented independently, without coordination, causing duplication in function and stovepiping of the data maintained. Many of these systems also use proprietary data repositories. As a result, data transport, control, management, governance, and ownership are not easily compatible or interoperable across network boundaries. Therefore, there is now large-scale duplication of data and a lack of interoperability, transparency, and effective management to ensure DoD-wide data quality, availability, integrity, security and usability. The Total Learning Architecture (TLA) is a set of policies, standards, and specifications, developed by the Advanced Distributed Learning (ADL) Initiative, that is driving the DoD's Enterprise Digital Learning Modernization initiative. The TLA vision features a robust data strategy that collects and maintains fine grained data across the learner's entire career arc. These data can leverage machine learning capabilities for personalization, adaptation, and recommendation across modalities, accommodating changes to the credential, the course content, and the trained systems, to support continuous improvement and validation of learning outcomes. The standards included within the TLA allow for fielding and sustainment of education and training solutions that dynamically change and grow in response to new technology, or new approaches to learning, while normalizing data these systems generate about human capability. The normalized data facilitates a truly global learning analytics capability and enables the enterprise-wide planning of individual lifelong learning journeys in support of an organization's human capital supply chain. This tutorial provides an in-depth understanding of the TLA data strategy and the future learning ecosystem it enables. It introduces learners to the core concepts of data interoperability and decomposes existing systems into the basic building blocks required to support lifelong learning. The TLA relies on four general data types including metadata about registered activities, the common definition of competencies required to perform different jobs, streaming data on learner performance, and enterprise learner records that manage data about experiences, credentials, and career trajectories. Attendees will gain a good understanding of the core TLA services that publish or subscribe to these data and transform them into meaningful information. General guidelines will be provided for implementing these standards, building an integrated data strategy, and managing the lifecycle of learner data across the DoD enterprise.

Advanced Distributed Network Architectures for LVC

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20028

The evolving live, virtual. Constructive (LVC) simulation training environment reflects the emerging battlespace. It is highly connected and the people and

systems that are working simultaneously as information collectors, forwarders, and consumers generating hundreds of thousands of information exchanges a minute. The ever-growing number of sensors and the associated demand for peer-to-peer, real-time information exchanges is compounding the effect suggesting the need for a zero-barrier exchange environment. The emerging environment challenges legacy the simulation & training construct, which has largely been built on stacks that provide a self-contained operating environment specific to a location. These legacy characteristics are limiting because when there is a change to underlying data sets and applications, as will be the norm in the future LVC environment, implementation across the full range of weapons systems is carried out on independent schedules via independent approaches that may alter the representation due to system-specific design limitations. The impacts are realized as concurrency gaps emerge and, in some cases, differences among system representation techniques create a non-level playing field. Over the past two decades, those local assets have been linked via connecting environments that minimally serve up common elements of the scenario to each participate via standards-based interfacing system but, the legacy model is characterized by platform-centric systems that operate on a self-contained computational environment to represent core platform and weapons system performance. The future of simulation & training will be characterized by development & delivery of scenario-specific, vendor agnostic data and applications. Getting to the objective state requires: a fundamental shift adopting a framework that eliminates barriers to exchange and collaboration across the entire simulation & training lifecycle - planing, preparing, executing, and assessing, incorporation of a rapid innovation capability; and an architecture to support cross-enterprise access from the labs, to the system program offices, to the intelligence centers, to simulation and training centers, to deployed mission rehearsal environments, to the units and to the individual. Achieving the objective of full spectrum LVC training requires an architecture approach that recognizes that shared data & and agile applications will power the future. Approaches that will deliver performance in an environment characterized by: real-time collective event orchestration and multi-participant collaboration; advanced software defined networking, elastic & extensible cloud computing; cross-constellation consistency in cybersecurity; and multi-dimensional SecDevOps and Multi-Level Security operations.

Distributed Interactive Simulation (DIS) 101: The Basics

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20031

The Distributed Interactive Simulation (DIS) protocol is a well-established IEEE standard for packet-level exchange of state information between entities in military simulations. DIS facilitates simulation interoperability through a consistent over-the-wire format for information, widely agreed upon constant enumeration values, and community-consensus semantics. Anyone can obtain the IEEE-1278 standard and implement their own compliant, interoperable, DIS application. A large variety of tools and codebases simplify this effort, and enable multi-architecture integration of simulations using the DIS stand baseline. DIS focus begins with real-time, physics-based, entity-scale simulations, providing state update and interaction mechanisms which can scale to large virtual environments. This tutorial is a “DIS 101” introduction for software implementers and an introduction to the DIS philosophy for simulation systems integrators. Examples are provided using the open-source Open-DIS library for DIS v7 and Enumerations support, available in multiple programming languages. Ongoing work is included in unit testing of DIS streams, and Web-based implementations using X3D Graphics, as well as Compressed DIS and DISv8 development.

Experimentation Campaign: Crafting the Future

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20033

oday we find the term “experimentation” in many documents, particularly those revolving around the topic of multi-domain operations (MDO). But what do we mean by experimentation? Do we all mean the same thing? Discovery experimentation and experimentation campaigns can be very powerful in exploring and defining new capabilities whether materiel or evolution of tactics, techniques and procedures to account for new challenges. Discovery experimentation is a process for using simulation to place emerging technologies in the hands of warfighters engaged in virtual battlefields to explore the military utility of new concepts for using emerging systems. Discovery experimentation is designed to allow learning and modification from trial to trial and in that way differs significantly for both traditional scientific experimentation and technology demonstrations. It can be used to explore military utility of new technologies, development of new tactics, techniques and procedures for emerging systems, definition of requirements for control devices for new systems, and consequent needs for new training. This tutorial will walk through the definition of discovery experimentation and experimentation campaigns, illustrating the concepts with a partial discovery campaign completed in 2016 to test a new concept in close air support. Using the definitions and example provided, the tutorial will go on to explore the potential roles of discovery experimentation and experimentation campaigns in the evolution of concepts and capabilities for multi-domain operations. The presentation will examine the roles of constructive and LVC modeling and simulation capabilities in addition to modified live testing, including the issues of data collection. The importance of scoping and choosing rapid modification of simulation tools will be highlighted as a means of making experimentation campaigns viable in a resource-constrained environment.

Live Virtual Constructive (LVC) Interoperability 101

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20040

The tutorial is intended for decision makers who have recently come in contact with distributed simulation and need a top-level understanding of Live, Virtual and Constructive (LVC) interoperability and the supporting standards, technology and processes. The purpose of this tutorial is to provide managers the necessary insight needed to support intelligent decision making. The tutorial will discuss the various domains of the technology and how it can potentially relate to their LVC needs. The tutorial provides a relevant use case as the mechanism to explain the concepts, processes and 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.

The Changing World of U.S Export Controls 2020

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20044

The past year has seen significant changes to the U.S. export controls, including the publication of the last categories of the U.S. Munitions List and the Commerce Control List to be revised under Export Control Reform and changes and updates to key definitions and concepts in the U.S. export regulations. This tutorial will provide an understanding of the International Traffic in Arms Regulations (ITAR) and the Export Administration Regulations (EAR) and the impact of the recent changes on the regulations and the export of controlled goods, technologies and services. The tutorial will examine the scope of the U.S. export laws, how the U.S. Government applies them to the simulation industry, including controls on software, hardware, services and activities at trade shows such as I/ITSEC, as well as discuss examples of products and services, and associated licensing strategies, in the current regulatory environment.