NTSA

NATIONAL TRAINING AND SIMULATION ASSOCIATION
THE WORLD'S LARGEST MODELING & SIMULATION EVENT

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TABLE OF CONTENTS

EDUCATION

EMERGING CONCEPTS AND INNOVATIVE TECHNOLOGIES

HUMAN PERFORMANCE ANALYSIS AND ENGINEERING

POLICY, STANDARDS, MANAGEMENT AND ACQUISITION

SIMULATION

TRAINING

TUTORIALS

PROFESSIONAL DEVELOPMENT WORKSHOPS

BEST PAPER

Practical Magic: Applying Guidelines to Serious Game Accessibility

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23225

Federal agencies (DoD see FAR Subpart 39.2) are Congressionally mandated to provide electronic and information technology accessible to people with disabilities. Exemption is allowed if accommodation would cause undue burden, would lessen the overall experience for most users, or if no conforming options exist, and exceptions hold for some military procurements. Prior authors have shared guidance on implementing accessible web-delivered courseware, but actionable creation guidance for accessible learning games has not previously been discussed.

Many serious games provide basic in-game accommodations and with exemption offer alternate, non-game content to meet users' needs. Our community should challenge ourselves to provide serious game experiences to a wider learner audience, accommodating disabled users through the assistive technologies they utilize in their daily lives. While this sounds easily agreeable, in practice barriers to providing inclusive gameplay are prevalent. The most used development engines render games inaccessible to assistive technologies, budgets are often lower than developers request even without accounting for accessibility requirements, and the learning games community lacks accessibility design guidance.

The widely recognized Web Content Accessibility Guidelines (WCAG) 2.1, originally developed for traditional web content, can be adapted to address accessibility in interactive games. Applied in this way, WCAG offers generalized themes useful for developers to extend and interpret as guidance for complex, dynamic user experiences. By designing to WCAG, developers can ensure that their games will be accessible to a wide range of users and create a foundation to communicate the accessibility level of products using a generally understood lexicon.

This paper offers the serious games community a practical guide to accessibility. Topics include: an overview of regulations, requirements, and consumer expectations for accessibility, WCAG introduction with concepts anchored by learning game examples, a comparison of implementing in-game versus assistive technology accommodations with lessons learned, and design challenge highlights from efforts to provide engaging gameplay for all.

Using Biometrics to Evaluate the Efficacy of Virtual Reality Learning Environments Through the Detection of Awe

Christopher Yockey
23109

Can a cartoon make you cry? Can it make you feel empathy? Until recently, my answer, apart from a certain Pixar movie about a widower and his balloons, would have been a resounding no. Then I witnessed a demonstration of a virtual training technology that changed my perception. I realized that virtual environments don't have to be completely life-like to be immersive. As virtual reality (VR) equipment costs have decreased, it has found many uses, especially in education and training. VR is effective in a wide variety of applications because of its ability to immerse users in relevant environments. Each application is unique and requires a different level of realism to be effective. Most organizations that want to use VR for education and training don't have large budgets to develop virtual environments, so the question becomes, how can a designer determine when their virtual environment is realistic enough?

The traditional way of evaluating virtual environments is to have users test them and report on the experience. This method can provide useful feedback, but it results in subjective answers that may not reflect the ability of the environment to promote learning. Advances in biometric sensors have made it possible to monitor a user's physiological responses while using a VR system. This paper explores the possibility of using biometric data to objectively assess a virtual reality learning environment's ability to encourage positive learning outcomes. First, it discusses the importance of immersion and presence in learning. Next, it provides an overview of several biometric measures and what they indicate about the autonomic nervous system. The paper then explores the awe effect and how it can be measured using biometrics. It then examines how experiencing awe leads to improved learning outcomes. Finally, the paper discusses the application of this evaluation method to the design of virtual reality learning environments.

Evaluate the Benefits of Employing Immersive Learning Techniques: Improve the Effectiveness of Sexual Assault and Prevention (SAPR) Training

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23120

In 1984, I was a 17-year-old civil servant, a teenager in a primarily male-dominated workforce; in the 1980s, this was a recipe for disaster. I was sexually harassed several times and suffered one physical attack—in the workplace, where I should have been safe and free to learn without being fearful. We have come a long way since 1984! Today's Zero Tolerance Policy has been effective in changing the culture of the 1980s. However, it is our responsibility to do everything possible to ensure Zero Tolerance is not just the goal or, worse, a catchphrase but the reality for every single Airman. There is a cost for this level of training. Nonetheless, we cannot afford the price of even one big-A Airman suffering from sexual assault or harassment.

Airmen receive state-of-the-art training for hard skills, such as piloting, maintaining, and sustaining billion-dollar weapon systems. The Air Force misses the mark when training soft skills, such as leadership, communication, listening, adaptability, teamwork, ethics, and respectful behavior. Understanding the nuances of Sexual Assault and Prevention (SAPR) training is more than the explicit, illegal behavior of physical assault; this training must teach the gray areas of harassment and prevention. Those gray areas include teaching consequential behavior, respect, reading body language, and many more skills not conveyed by

PowerPoint presentations. Today's digitally native workforce is most comfortable online, making soft training skills more critical than ever.

The standard training method for SAPR is low-tech and non-immersive. This paper contends that the Air Force would improve SAPR training by employing immersive learning techniques. This paper will utilize Ruscella's and Obeid's Taxonomy for Immersive Experience Design chart 2021) to measure the effectiveness between PowerPoint training and several immersive experiential training methods. The result will provide evidence to support the investment in immersive technologies to improve programs across the Department of Defense.

Examining Full-Spectrum Embedded Training Modules for a Crew's Task Simulation Task

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23130

An embedded training (ET) system leverages an operational platform to provide a learner with point-of-need training. Traditional learning methods need to meet today's fast-paced learning environments and keep up with ever-changing, real-time information flows. This study examines ET modules for a tank; training materials development explored designs that go beyond instructional slides, handouts, and videos. The ET module types include immersive 3D simulations, synchronized voice instructional trainings (SVITs), and tour guides (i.e., automated click-throughs), giving the learner variations of training information to learn at their own pace and given the time available to train. This research effort examines the feasibility of the ET modules to instruct nine soldiers (three, three-person crews; each crew containing a driver, gunner, and commander) operating a tank simulator to complete a set of tasks. The ET tasks were driving, threat identification, and route planning. Each crew completed a pre-test questionnaire, then operated the simulated tank while interacting with ET training modules, and then answered a post-test questionnaire. Keystrokes and button presses comprised the performance data collected during training. The soldiers also provided usability feedback on the ET system through a questionnaire. Anticipated data analysis includes trends in user feedback, a comparison of pre- and post-test responses; and descriptive statistics (as means, standard deviations, and outliers) for the performance data. The findings will explain the ET's feasibility, offer high-level performance results, and provide insights into user perceptions. Recommendations will consider the ET's strengths, challenges, and areas for improvement. Future ET applications will focus on working digital-instruction creation and design, electronically available instruction for brief or classroom style learning, courses, and simulation training library build-outs.

Teaching Simple Combat Models through Spike TV's "Deadliest Warrior"

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23142

Combat models allow military analysts and leaders to analyze potential conflicts and evaluate different technologies and tactics. While there are a number of combat simulation packages available, they can be narrowly scoped and often require complex software that can be difficult to learn. As such, it is essential for military leaders and analysts to be able to develop simple combat models to analyze conflicts that are out of scope of current simulations. To address this need, a course project was implemented in a combat modeling course at the United States Military Academy to teach students this valuable skill. This project was inspired by the show "Deadliest Warrior," which modeled a fictional conflict between two temporally and/or geographically displaced fighters (e.g., a Samurai fighting a Viking). The course project required students to identify two combatants and research their lethality and survivability. After conducting this research, each student built a stochastic model in Microsoft Excel to identify the percent of runs where each combatant wins. This project reinforced numerous principles of combat modeling, forcing students to perform background research, critically analyze the two warriors, make assumptions, build a stochastic model, perform verification and validation, and analyze the results. This paper presents the assignment, examples of products produced by students, feedback from students, and a compilation of lessons learned. Generally, the feedback from students was positive with most students indicating that they enjoyed the exercise and developed a deep appreciation for the nuances of combat models. By requiring students to build simple combat models, the course project successfully taught a valuable skill that is essential for military leaders and analysts.

Generating Procedural Knowledge Test Items Using Natural Language Processing Techniques

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23157

Among the most useful information in field manuals are descriptions of the procedures for certain tasks. While the assessment of procedural knowledge is typically performed using hands-on exercises, testing the recall of such knowledge could be beneficial for several reasons. First, it could serve as preparation for hands-on assessment. Second, it could also aid knowledge retention through mental rehearsals. Third, it can aid personnel in self-assessments. Finally, assessing knowledge of procedures is beneficial when the cost of failure is high. Successful implementation of procedure extraction from manuals will pave the way for automatically developing assessment criteria for simulation-based or hands-on performance assessments as well. For example, the skill throwing a hand grenade is best assessed through hands-on performance, but assessing recall of the procedure provides opportunities for testing recall before a hands-on assessment. With these benefits in mind, we investigated the potential for natural language processing (NLP) technology to accurately identify and extract descriptions of procedures from documents and construct assessment items from them. While neural network-based approaches are increasingly popular for NLP, we hypothesized that a linguistic patterns-based method would be sufficiently powerful for this task. We have implemented one such technique for procedure description extraction and subsequent generation of a test item based on the extracted procedures. We evaluated the performance of this approach in creating high quality test items that would be useful

in practice. This paper will describe the technique used, provide examples, and describe a validation study to evaluate the results. It will also discuss the challenges that need to be addressed to improve accuracy and utility. The purpose is to demonstrate what level of accuracy is achieved with a rule-based approach and pave the way for future improvements.

Toward a Theory of Human-AI Co-Learning and Trustworthiness

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23163

Looking to the future, the battlefield promises to be exceptionally complex. To maintain overmatch across competition and conflict, it is likely that warfighters will increasingly rely on artificial intelligence (AI) teammates. A key issue that emerges is the extent to which AI are trusted, and ultimately, whether AI "trust" humans. Simply put, gains in overmatch cannot be achieved in absence of a foundation of trust in other intelligences that enables collective speed, awareness, and adaptation. The advantage of interdependence is emphasized historically in the context of Mission Command, and it will continue to be true with AI partners. The challenge is that trust can be perceived as elusive and as such appear difficult to assess and train. However, we illustrate how trust can be understood by appealing to behaviorally observable indicators of trustworthiness. A programmatic strategy for human-AI trustworthiness should (a) identify actions of other intelligences that, in context, are indicative of trustworthiness, (b) describe how such actions and the context for them are observable and measurable, and (c) develop training for observation, orientation, decision and action (OODA loops) of humans and AI to utilize such observables. To ground these claims, we review evidence of how seemingly elusive human traits (e.g., character as well as competence) have been shown to be observable and trainable by leveraging the micro-experiences inherent to everyday military settings. Likewise, we illustrate how AI already exhibit behavior that is similarly observable and consequential. We emphasize the trajectories of co-learning among entities that adapt their OODA loops based on their shared experience in context. These trajectories are continually shaped, with good or bad outcomes, whether intended or not, and whether attended to or not. Yet, by leveraging observables, these considerations are neither elusive nor abstract. They are concrete and right before our eyes.

Leveraging Sports Psychology to Improve Team Performance Huddles

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23171

As a form of interim or formative feedback, a sports timeout can provide effective instruction and lead to peak competitive performance (Andrews, 2015). A timeout is spontaneous and brief and can serve as an intervention to improve performance on the spot. Conversely, an after-action review (AAR), which is a summative feedback technique frequently used in the Army, is deliberate, comparatively lengthy, and after the fact. The U.S. Army Research Institute (ARI) is conducting research aimed at improving the assessment of hard to measure team constructs during live training and determining how to help instructors and trainees better understand the impact of those constructs on performance. Further, ARI is interested in feedback approaches that allow an instructor to effectively address these constructs. As such, the present research applies an interim feedback approach with small ad-hoc squads during a simulated tactical combat casualty care training exercise. This approach (termed the squad huddle) was designed to last approximately three minutes, led by an instructor during a transition from one set of tasks to another, similar to a sports timeout. The research team explored relevant sports psychology literature to identify characteristics of effective timeouts. Further, the team reviewed extant feedback literature to incorporate best practices in the huddle design that would allow the instructor to reduce ambiguity around goals and standard performance (Gregory & Levy, 2015), reduce cognitive load on the huddle participants (Sweller, 1988), balance positive and constructive feedback, and ensure psychological safety. The literature search resulted in a carefully designed squad huddle that was iteratively refined based on Army instructor feedback. An experiment was conducted to field test the efficacy of the huddle with favorable results. Data (mean score differences) indicate that such a feedback approach may benefit trainers, instructors, and educators as they seek to improve small unit or group performance.

Using Non-immersive VR Simulations in Conjunction with Priming to Enhance Conceptualizing Radiation and Risk

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23174

Radiation is present daily and used throughout many industries for beneficial purposes. Safety professionals and workers need a general understanding of radiation identification techniques and associated risks to manage the work environment with radiation protection practices. This is especially important in workplaces where the radiation source is ancillary to the primary activities of the industry. The elusive nature of radiation makes learners understanding in an educational setting a challenge. Furthermore, delivering a hands-on experience to support learning and training of radiation, its assessment, and protection measures is quite difficult, given its hazardous nature.

Virtual reality offers significant benefits through simulating sources of radiation. A simulator, AssessRadVR, facilitated the radiation experience and presented the dynamic effects of the trainees' interactions with shielding materials, detection equipment, and the working environment. Yet, interaction with simulation alone may not trigger effective encoding of these critical aspects in long-term memory.

This paper discusses using AssessRadVR in conjunction with a procedure for subliminally priming the long-term memory encoding to enhance radiation's activated representation. Students in an introductory industrial hygiene class were divided into two groups

and primed with either alarming or non-alarming words following the Berg, Chen, & Borrows procedure (1996). Upon completing the simulation in AssessRadVR, students submitted reports and surveys that provided their interpretation of the identification of radiation types, a proper radiation protection plan, and their overall perception of the risk of working in the environment.

Why is this of interest to the community: The results provided that even with limited prior knowledge in radiation, after engaging in AssessRadVR, most students were able to recognize and apply radiation principles, which indicates they could apply key principles in a real-world radiation workplace. Further, the impact of activating with alarming words led to a statistically significantly higher perception that working in the radiation environment was manageable.

Leveraging Machine Learning and Cognitive Science to Enhance Knowledge Retention in Air Force Special Warfare Trainees

Amy Smith

23196

At the core of every good decision is a strong knowledge base. Making fast and accurate decisions in high-stakes scenarios requires effortless and automatic recall of important information. Despite this fundamental truth, military training dedicated to cognitive human performance is underemphasized in training relative to physical human performance. To address this discrepancy in their training of airmen, the 351st Special Warfare Training Group (SWTG) at Kirtland AFB implemented a tool called Blank Slate with their trainees in 2022. The Blank Slate app uses the most robust learning techniques from cognitive science to help users effortlessly retain the knowledge they need to perform, while leveraging machine learning to track users' forgetting curves so that users are only prompted to review information when they are most likely to forget it. Of particular interest to the SWTG was enhancing trainee retention of detailed paramedic training. Over the course of one year, over 70 trainees across three different classes at the SWTG used the Blank Slate app regularly to answer questions about their course content. Results from this pilot study showed improvements in trainee knowledge retention from the beginning to the end of their course, and a reduced risk of failing their course relative to trainees who did not use the app. Furthermore, because the Blank Slate machine-learning algorithm makes the tool maximally efficient, these positive outcomes were achieved for less than an average of 40 seconds of engagement with the app per user, per day. These findings highlight a positive development toward efficient and effective uses of technology to support knowledge retention in military training and, by extension, support high-level decision making.

Using Feedback to Increase Engagement with Adaptive Training Tools in USMC Classrooms

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23199

To modernize training in the Marine Corps, Force Design 2030 and Test & Evaluation 2030 have emphasized the need to integrate technology into classroom instruction that tailors course material to individual Marines. Several innovative adaptive training (AT) solutions have been developed to address the modernization effort that leverage science of learning principles using learners' in-training performance to tailor instruction to the individual.However, these training solutions often are offered as supplemental resources for students to use on their own time. AT systems have been shown to increase learning outcomes in military classrooms for students who opt to use it. For example, in a pilot study conducted by Whitmer and colleagues (2021), an adaptive flashcard system was provided to Automotive Maintenance Technicians Basic Course (AMTBC) students to use at their discretion on course-issued laptops. The researchers found higher usage was associated with higher course GPAs, and the cohort with the AT experienced fewer exam failures compared to a previous cohort without AT. Interestingly, they also found system usage varied widely with many students choosing not to use it. As a follow-up to this research, we investigated whether engagement rates could be increased by presenting performance-based feedback at regular intervals. Previous research suggests that feedback paired with studying (e.g., flashcards) can increase motivation to continue studying (Abel et al., 2020). To that end, we partnered with AMTBC and provided students across four cohorts with one of two versions of an AT flashcard system. One version presented performance-based feedback at regular intervals and summary feedback at the completion of a session, while the control version did not. Results show that overall AT usage related to higher course performance and students in cohorts receiving feedback completed more flashcards. Implications and recommendations for increasing student engagement with modern training approaches will be discussed.

A Review of Research Discussing Analysis of EEG Data During Training and Skill Transfer for Skills Learned in Virtual Reality

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23285

Muscle memory can be defined as the ability to reproduce a physical movement without conscious thought and is acquired from repetitions of that movement. Many skills can be learned by applying training routines in the physical world to build muscle memory so that the skill becomes second nature. However, at times the skills may involve material requirements that may restrict the ability to perform the training in a real-world environment. At the same time, Virtual Reality (VR) provides an environment where the required material can be simulated and potentially remove restrictions that exist in a real-world environment. Previous studies have shown that VR can be used to successfully train users in

skills consisting of repetitive tasks. Other research has shown how electroencephalograph (EEG) techniques can be used to analyze brain activity during learning. This paper expands on previous work from both areas to correlate findings between using VR for skill training/transfer learning and analysis of EEG recordings taken during training sessions to highlight potential similarities in learning in both environments.

From Classroom to Field: Topological and Tactical Terrain Analysis Inside a Learning Environment

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23299

The present work is about a solution for the Military Academies to improve the teaching process of analyzing the Topological and Tactical aspects of any region by modeling any georeferenced region and bringing the classroom resources to that learning environment.

By opening the possibilities to train the students before the actual exercise or even planning Operations at any time needed, they will be more prepared when the time to go to the terrain exercise arrives. Using several interfaces like Virtual Reality (VR) headsets to get a better immersion, a projector to follow the progress of the exercise, or a tablet to keep interacting even outside the VR, instructors and students will be able to interact inside and outside that world through those interfaces.

In addition to that interaction, the possibility to share between them classroom resources like presentation slides, whiteboard scratching, the possibility to draw in the terrain, insert animations with military resources, changing climate conditions, and much more will help instructors to pass and standardize knowledge more efficiently.

This paper is important to the community because these platform resources can offer both education and real situations capabilities to better understand terrain analysis or even situation awareness. Moving the classroom to a conflict area to analyze the terrain may result in time-consuming, budget costs and other several expenses. Using Virtual Learning Environments makes it possible to teach several students at once in a classroom changing the area anytime you want and fast. Another aspect is that it could combine those interfaces and interact with them, making it possible for everybody to plan exercises by simulating an area and in that area putting animations of the enemy activity and exploring Military Planning Process.

Advancing Career Aspirations in STEM Fields through Co-Design and XR-Enabled Educational Delivery Models

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23301

By 2028, the U.S. will have the largest number of foreign-born individuals since 1850 with non-hispanic whites in the 18-29 age group in the minority. These changing demographics require a major shift in education practices that will affect these residents', and organizations wanting their labor, ability to continue their education, get/recruit for a career, enlist/recruit in the military, and simply navigate in a digital society. Many of these residents have a range of challenges from language barriers to lack of access to the Internet and mobile devices that must be addressed.

XR technologies, interwoven with learning theories, offer solutions to these challenges. This paper presents a study of XR-enabled educational delivery models with the community of Storm Lake to enhance students' aspirations for STEM careers. Storm Lake is a rural Iowa community with a large low-skilled workforce employed in the agroindustrial sector and a K-12 student population that is 64% English Language Learners and 85% students of color. The research began with co-design activities (formal process actively involving all stakeholders) with teachers, students, and families in the community, without technology use. Analyzed study data showed that traditional technology development and deployment practices wouldn't effectively educate or inspire students. For example, providing teachers with XR devices creates a training burden to properly operate, often resulting in unused technology. Another outcome was that co-design activities, with place-based challenges in XR environments, was effective for students to learn STEM-related content. Co-design activities concluded in a three-day summer workshop for 11 high school students. At the workshop, students defined a place-based challenge in their community and implemented an XR technological solution in software and hardware. Assessments following the workshop showed very positive results from the students on several measures and culminated with seven of the 11 applying to a university in a STEM major.

Virtual Reality Provides Real Data: How Data in VR Transforms the Concept of Readiness

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23375

NATO highlighted the possibilities of AI for military applications: "The main ingredient in any ML-application is data…military organizations may have to adapt their data collection processes to take full advantage of modern AI-techniques" (NATO, 2018). To do so, we need to change the way we currently classify learning from multiple choice questions to quality objective data (Schatz & Walcutt, 2022). Before 2019, VR in education relied on pre and post-tests, questionnaires, interviews, scales, focus groups, and observations (Çanakaya, 2019). These methods are labor intensive, consist primarily of qualitative approaches, and do not support the rich data needed to build AI into the training pipeline. In the past 5 years, researchers and engineers have been finding ways to incorporate objective data into VR systems. Human state examples include: eye tracking (Ahuja, et al., 2018), heart rate and respiratory rate (Floris et al., 2020), EEG data (Tremmel et al., 2019), and facial expression tracking (Houshmand, 2020). Commercial off-the-shelf headsets have begun integrating human state data as well as cameras and sensors that provide opportunities to understand motion, where trainees spend time, their interactions, and every nuance of how they complete their training tasks. Tracking data

within a VR training exercise provides insight into who needs additional training, when AI virtual instructors could assist, the level of readiness, the likelihood of trainee success, and detecting points of failure in the field to gaps in training. This paper will address the ambiguity of what kind of data to use for different training applications, how to pull data from VR systems, how the training pipeline could use this data, and examples of how data was built into various VR training tasks developed by an Air Force Research Laboratory with lessons learned and guidance.

Understanding STEM Education Opportunities to Build the Future Workforce

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23392

The possibilities for building and maintaining a science, technology, engineering, and mathematics (STEM) workforce need better explication to serve the needs of government, industry, and academia. Understanding the portfolio of Department of Defense (DoD) initiatives to educate STEM practitioners provides information that may benefit programs with similar goals. DoD's requirement for STEM talent is particularly acute as it seeks to replenish and expand a workforce estimated at over 150,000 STEM professionals working as DoD civilians. In this presentation, we describe the findings from a portfolio evaluation of 50+ work experience programs (e.g., internships, scholarships, postdoctoral positions, and new hire incentives) that the DoD conducts to educate an estimated 5000+ participants annually. These programs are designed to inspire, cultivate, and develop students and early-career professionals. They use a variety of methods to attract participants, provide mentorship, and prepare students for a career as a STEM professional. The opportunities are broad, covering all types of STEM disciplines at multiple levels of education (high school, undergraduate, graduate, and post-graduate), conducted across the country. Approximately 75% of the programs recruit from a national pool of applicants, and some of the larger programs offer opportunities at 30+ sites (e.g., DoD facilities, university labs, and contractor sites) at locations across the country. There are also specialized programs that focus on a particular discipline such as cyber and artificial intelligence, center on a local community to attract talent to the area, or foster participation of students in traditionally underrepresented groups. A common outcome for participation at advanced educational levels is being hired after graduation. This paper will help inform others about options for engaging and developing STEM professionals for the workforce of the future, and how these programs can benefit both the participants and the organizations that conduct them.

Disrupting the Status Quo: Nursing Curriculum Transformation with Virtual Reality

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23428

Nightingale College's continuous focus on innovative, evidence-based design keeps the organization disrupting the curricular status quo with new higher education approaches and curriculum resources. In one initiative, the College partnered with Oxford Medical Simulation (OMS) to implement a multi-phase rollout of the use of virtual reality (VR) to deliver a hands-on, simulated nurse training environment. Learners use VR headsets to apply their skills and knowledge in the safety of a virtual environment that mimics real-life nursing situations. They are immersed in typical nursing scenarios, including diagnosing patients, instigating treatments, and interacting with the interdisciplinary team. They may repeat experiences as often as they like, with the system offering multiple adapted outcomes based on their responses to fully interactive, simulated patients and their family members. They also receive personalized feedback, performance metrics, and a synchronous faculty facilitated debrief. Initial pilot data indicated excellent student feedback and improved outcomes in critical thinking and clinical reasoning, and data from the full program rollout of this resources continues to trend upward. The College continually searches for new ways to innovate in nursing education through its full-distance education model to improve outcomes and solve issues across the nursing profession, including the nursing shortage. This allows for effective execution of the institutional mission and contributes to the realization of health equity.

Within this paper, the authors will share the multiphase approach toward implementation of the use of VR in nursing curriculum and discuss the challenges and interventions implemented between the initial pilot, previously presented, and full program rollout. The presenters will share updated data around learners' improvement in clinical reasoning skills using VR and testimonies of learner experience throughout the program. Additionally, the authors plan to discuss future augmentation of this initiative, including partnering in the creation of customized VR solutions based on identified curriculum gaps.

Learning to Learn: The Trials and Tribulations of CBE Implementation in Technical Training

Nathan Jones • Nate Ferrara

23455

Competency-Based Education (CBE) has gained popularity in technical trades education. This paper examines the implementation of three CBE programs for technical trades and the challenges encountered during the conversion and implementation processes. While the programs have demonstrated significant benefits for technical training, including optimized student learning and scheduling, it is apparent that the implementation process presents numerous challenges. These challenges include selecting a Learning Management System (LMS) that balances administrative needs with a learner-centric user experience, transitioning from traditional instruction to coaching and mentoring, motivating learners, facilitating student progress in a varied pace environment, utilizing a registration process that tracks learning progress rather than calendar-based scheduling, managing online learning content, and tracking student progress across multiple courses simultaneously.

Addressing these challenges requires a concerted effort from instructors, administrators, and policymakers. Implementing competency-based education programs for technical trades can

lead to significant improvements in teaching and learning, provided the challenges are addressed comprehensively. To this end, instructors must adopt a coaching and mentoring approach that guides learners towards practical application and mastery of skills. Learners must also be motivated to understand the relevance of the skills they are acquiring and provided with personalized learning experiences that cater to their unique needs. Instructors must acquire proficiency in novel methods of student engagement and interaction while ensuring that the online content remains pertinent. Furthermore, they must track the progress of students across multiple courses simultaneously.

Despite these challenges, proper investment and attention to these issues can result in significant improvements in teaching and learning. This paper presents insights and lessons learned from CBE implementations, providing a valuable resource for educators, administrators, and policymakers interested in the effective implementation of CBE programs for technical training.

EMERGING CONCEPTS AND INNOVATIVE TECHNOLOGIES

BEST PAPER

Wires Crossed in a Digital World: How to Prevent Misalignments in Human and AI Decision Making

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23273

A boom in AI technology and presence has made AI virtually omnipresent across domains. However, an important aspect of AI adoption is the level of trust and perceived competency of the system by the human (Hancock et al., 2011). When done seamlessly, such as Google's search algorithm or Netflix's "Trending Now" feature, humans are provided with results that are germane to their needs, historical interests, and are more naturalistic in interaction; ultimately increasing their perception of the systems competence (Low et al., 2021). Therefore, it is of high importance to ensure that systems are designed in a way that promotes users' trust while providing them with the support that they need as we look to integrate decision-support AI into intelligence, mission planning, and JADC2 applications. This paper presents the design of a novel system intersecting human factors, cognitive modeling, and recommendation AI to explore approaches for collaborative human-AI teaming. Under this effort, a web-based decision support AI provided recommendations for publicly available articles to answer an intelligence analysis priority intelligence requirement (PIR). We conducted a series of usability and system design evaluations that explored (a) information that users consider when making trust judgments, (b) unobtrusive behavioral measures that integrate into cognitive models to predict when trust falls, and (c) trust calibrations when cognitive model predictions did not match user actions—providing the AI an opportunity to build trust by intervening at the right time in the right way. User behavior, impressions, and self-report responses were examined to understand what user behaviors emerge when users perceive a tool to be working collaboratively. Specific guidance on designing recommendation AI that can leverage behaviors and cognitive modeling for naturalistic interaction as well as system calibration techniques to improve a user's perception system competency are discussed.

Demystifying 5G for Extended Reality (XR) and Spatial Computing: Five Critical Lessons from a Year in Independent Research and Development (IRAD)

Michael Zurat

23104

The future of XR training and simulation appears to be some variant of the "metaverse". One thing most vendors and technologist agree on is that this "metaverse" will be powered by 5G and XG wireless technologies allowing ubiquitous connectivity while balancing massive amounts of sensors and smart devices and objects. That said few people have ever actually used an XR device connect to a private 5G network in an arrangement similar to what the future "metaverse" will rely on as its critical backbone. General Dynamics IT and its 5G and Edge coaltion partners launched a Private 5G lab in January 2022. Nearly two years into the experiment we share lessons learned about the reality of using, deploying, integrating and connecting VR, AR, MR, volumetric video displays, holographic teleconfrencing devices and XR devices over a private 5G network.

AI/ML-driven Network Optimization to Enable Synthetic Training and Distributed Simulation

Jack Burbank • June Gordon • Todd Lutton • Gregory Patti • Ebony Robinson • Antonio Fiuza • Brad Friedman

23114

Any federated simulation environment or synthetic training environment will be only as good as the network that interconnects their various components. A poor performing network will limit the ability for real-time or near real-time distributed simulation and will limit the ability to deliver an effective synthetic training experience. Low-capacity networks can unacceptably constrain the types and amounts of data that can be shared across the environment. Low performing networks can lead to unacceptable latency that will translate to a poor user experience. The network must be able to provide both the capacity and performance to enable these key simulation and training paradigms. This becomes even more true with the emergence of performance-sensitive technologies such as Augmented Reality / Virtual Reality (AR/VR).

This paper presents the High-Performance Synthetic Training Environment (STE) Optimization Network (HP-SON), a capability currently being developed by Sabre Systems, Inc. for the US Army Futures Command Synthetic Training Environment (STE) Cross Functional Team (CFT). Born from the desire to inter-connect a

wide range of geographically distributed simulation and training elements across a variety of network types, HP-SON incorporates a suite of artificial intelligence / machine learning (AI/ML) algorithms to optimize the network to enable the Army's full large-scale, distributed vision of the STE. HP-SON's AI/ML employs state-of-the-art AI/ML algorithms to learn and predict network performance and user activity, resulting in a highly-reliable set of predictive network analytics. These predictive network analytics are then used to drive several predictive AI/ML-driven features, including data compression, traffic scheduling, protocol optimization, and forward data caching. Together, these capabilities dramatically improve perceived network performance and capacity and produces an improved user experience.

An Approach for Visualizing Comparison of Human and AI Decision-Making

Henry Phillips, Ph.D. • Alyssa Tanaka, Ph.D. • Angela Woods

23122

The task of consolidating and quantifying complex decision-making across a multi-attribute space is a challenge (Achkoski et al., 2017; Klein, 2008). This work describes a technique for quantifying human expert multi-faceted decision-making in the context of medical triage into a limited number of dimensions. The analytic and visualization technique described here also serves as a basis for both machine-readable and human-interpretable comparisons between human and algorithmic decision-making outcomes.

Tactical Combat Casualty Care (TC3) and medical triage scenarios involve complex situations comprised of factors including time pressure, high stakes, and uncertainty (Joint Trauma System, 2020; Klein, Orasanu, Calderwood, & Zsambok, 1993). Medical triage scenarios are an exercise in satisficing, since by its very definition, "triage" refers to the prioritization of limited tasks and resources. In complex triage scenarios, experts will disagree on what set of decisions is truly optimal (Achkoski et al., 2017). This effort used a dataset of 28 scenario responses from practitioners to capture complex triage decisions and translate the factors underlying them to quantifiable, comparable metrics. This modeling is a critical prerequisite for a measurement and visualization tool that could lend itself to comparisons of decisions made by human experts with decisions made by AI systems.

The goal of this effort was design of a simple system for representing and capturing treatment and resource allocation decisions by triage managers and translating those decision data to a limited number of dimensional attribute scores describing the decision-makers. This reduction made it possible to consolidate this representation of the data representing a group of decision-makers in a single multi-dimensional index. Machine learning techniques were then used to evaluate the predictive relationships among scenario characteristics and decision-maker attributes, also discussed (Zheng, Aragam, Ravikumar, & Xing, 2018).

Considerations for Adapting Training Technologies for Manned-Unmanned Teaming Operations

Scott Scheff • John O'Malia • Beth Atkinson • James Pharmer, Ph.D.

23125

Future concepts for mission execution and platform capabilities on programs such as Future Vertical Lift (FVL) generate expectations for pilot skills to manage vast data sets while interacting with autonomous assets. As a result, there are several considerations for training pilots in preparation for advanced teaming tasking including communication, trust, and workload balance (Anania, Atkinson, Frick, Pharmer, & Killilea, 2020). From a workload perspective, training that provides pilots with an opportunity to learn to deal effectively with dense data volumes and to coordinate with autonomous systems and unmanned assets will be critical to successful operations.

As part of an on-going effort to develop training technologies and tools to assist with workload evaluation and mastery, a series of interviews were conducted with pilots from existing Department of Defense platforms. The goal of these interviews was to establish a baseline understanding of the types of automation currently available to pilots. These interactions provided an opportunity to identify challenges associated with employing automation in operations, and to utilize pilot insights to optimize training processes associated with the adoption of new technologies. This paper reviews themes generated from these interviews and provides insight into the types of emerging and innovative technologies that might facilitate the workload training needed to produce proficient future pilots (e.g., how pilot training, alongside Artificial Intelligence (AI) systems, can shape and improve AI systems themselves. Findings address existing automation (levels and challenges), future increases in automation (perceptions and barriers to adoption), factors impacting operator trust of automated systems and AI, and methods to improve training (technology and pipeline). Discussions focus on the design of a learning management system that integrates human performance modeling and simulation based-training to offer near-real time iterative training to improve: teaming, situation awareness, technology understanding, and pilot workload management.

How Immersive Technology Augments Operations Centers

William Liggett, III • Andrew Clayton, Ph.D.

23134

Operations centers are designed to bring together and assimilate massive amounts of data for commanders to make decisions in reaction to real time stimuli. They provide command and control, continuity of operations, and resources required to sustain operations. The scope of responsibility often requires a large support staff dedicated to processing a significant amount of time sensitive data. Immersive technology can augment decision cycles in operations centers by intuitively representing complex data in physical space, enabling users to more easily understand and process that data. Additionally, virtual spaces can bring personnel closer to the action who may not physically sit on the operations floor due to space constraints or geographic proximity. Immersive technology offers Commanders the flexibility to maintain an

operational and training environment in the same space. Imagine a scenario where trainers interact with trainees in a virtual space that so perfectly overlays on top of the operations floor the trainees believe they are actually in the operational space? What if, in this scenario, trainees interacted with real world data and through their training experience offered solutions Commanders could use to solve current problems? In operations centers with a classified mission, immersive technology could enable multiple levels of access through existing access control mechanisms without having to lower the overall classification of the physical ops floor. This environment could significantly increase collaboration, efficiency, improve partnerships, and open the structure of operations centers to configurations that may have previously challenged operations security. This paper will examine the implementation of immersive technology into an operations center by exploring the benefits of augmented and mixed reality through the concept of presence, experiential learning, virtual displays, training, and parallel virtual collaborative environments.

Visualizing Cybersecurity Data for Detection and Assistance in Cyber Operations

Jason Ingalls • Judson Dressler • Kaur Kullman

23137

Cybersecurity has reached the point where the victims of cybercrime are far outnumbered by malicious attackers, and our means to defend lack efficacy due to bottlenecks in how we ingest, analyze, and react to the ever-growing amount of data required for cyber analysis.

Improvements in the amount of data that can be put in front of a human will only partially and marginally provide performance improvements. We cannot continue to “add more monitors” to accommodate the increase in data, and adding more computational power has noticeable benefits but is still far inferior to the “next step” of cyber analysis innovation.

Emerging 3D Cybersecurity Data Visualization will provide accurate interpretations of the battlespace by:

Lowering the barrier to entry into cybersecurity by creating a tool for the untrained to contribute to the Detection and Hunting of anomalies through an intuitive visualization language and control interface combined with a personalized Artificial Intelligence (AI)-assisted virtual training partner within a 3-dimensional (3D) virtual environment.

Eliminating the bottlenecks of 2D data visualizations (spreadsheets) by creating a tool focused on data immersion, human-intuitive data visualization, and manipulation while enlisting more of the human senses such as sight, sound, and touch in a 3D-surround virtual environment that takes advantage of graph database relational structure.

Immersive data visualization is key to easier adoption of cybersecurity and aims to break through cyber analyst performance. Immersive training is known to increase intuitiveness and educational receptibility. This is a new perspective and implementation within cybersecurity, where spreadsheet data structures and querying databases is the norm.

Simulation Model Abstraction Issues for Digital Twins; Separated at Birth?

Simon Skinner

23138

Digital Twins are seen as a potential solution for many difficult problems in developing military platforms; by keeping a physical asset and a simulated virtual twin in constant communication with each other, they offer the potential to improve operational performance and reduce the cost of development, test and evaluation, production, maintenance, training and support of complicated ‘systems of systems’, with the added benefit of providing flexibility in today’s rapidly evolving threat environment.

In the development of Digital Twins, the requirement to have validated and verified models of components which accurately reflect real world physical assets and processes as well as the aggregated systems containing them is key to their use. Despite massive advancements in compute power it nevertheless is not possible to represent everything at the highest level of fidelity for many applications, and the alternative of having different models which are not related to each other poses significant problems as well.

This separation of models ‘at birth’ poses a threat to the implementation of viable, interconnected Digital Twins, due to cost and configuration issues, particularly in the military context where the sharing of computer models, simulations and physical platforms with Allies and with Multi-Domain Integration across Land, Air, Sea and Space is increasingly important to sustain a global force able to flexibly adapt to changing situations.

In the context of a 9 nation research task being undertaken by the NATO Modelling and Simulation Group and elsewhere, this paper analyses the lessons of the past as they apply to model abstraction, with an analysis of potential solutions including the use of Artificial Intelligence techniques which will enhance the development of interconnected, interoperable and useful Digital Twins for the military end user.

How Large Language Models Translate Raw Data into Expert Rules

David Noever • Joseph Regian

23139

The research highlights how the latest large language models (LLM) can transform a corpus of technical knowledge into a formal ontology, then score the output as a customized expert system. Traditional ontology-builders support expert systems that humans can audit and explain the rules for trust and confidence predictions. A notable shortcoming of building ontologies from scratch involves the initial knowledge transfer from experts and curating the valuable generation of conditional rules and decision trees. The research experimentally examines whether converting unstructured data into structured candidates could accelerate rule extraction beyond just entity extraction for people, persons, organizations, or intent prediction for motivations or risk management. Our work highlights the historically significant DoD challenges first spearheaded by investments in massive symbolic artificial intelligence projects like Cyc (similar to enCYClopedia). The original ontology commitment of labor alone exceeded 1000 to 3000 person-years of effort “to

describe how the world works." The latest LLMs (such as OpenAI's GPT-3, Google's PaLM, etc.) typically encode 40 terabytes of the world's (internet) knowledge and provide convenient question-and-answer APIs that can export ontology-ready rules and semantic relationships to support deterministic expert systems. The research examines the experimental scalability of this approach for two examples taken from classic military training problems: 1) how to build verifiable medical diagnostics and decision trees for supporting field doctors; 2) how to build advanced decision aids for fusing situational and threat awareness and commander's dashboards. We evaluate these case studies for the LLMs and human questioners who extract artifacts for building expert systems. This process potentially solves the lack of reliability from existing LLMs and human feedback to solve the otherwise intractable needs for predictable medical or combat decision-makers. If the LLMs distill the world knowledge, then human inquisitors distill the expert artifacts in reliable and testable ways that remove indeterminism from existing dialog generators.

Neural Activity Mapping of Army Aviation Flight Task Performance

Christina Parker, Ed.D. • JJ Walcutt, Ph.D. • LT Nicholas Armendariz, USN • Dhiraj Jeyanandarajan

23145

The following paper explores how Army Aviation could leverage the neural pattern mapping of cognitive activity during flight task performance for curriculum design as well as learning and performance modernization that directly supports multi-domain operational environments. This study introduced a commercial-of-the-shelf (COTS), eight (8) non-contact node EEG device into a cap and through iterative exploratory research methods sought to establish and confirm both learning and learned neural activity patterns for performance of five selected rotary-wing flight tasks. This initial research collected performance and demographic data on rated aviators as the control group and non-rated aviators or aviation students not yet enrolled into the Initial Entry Rotary Wing Common Core (IERWCC) Course as the experimental group. The first step of analysis, using statistical testing and device specific machine learning analysis, were compared to establish differences and baselines of learned (control) and learning (experimental) flight task performance neural activity patterns. Learning pattern baselines considered the following: 1) what learning neural patterns looked like in comparison the learned neural patterns and 2) the time it took to progress through learning patterns to learned patterns. The second step compared experimental and control group neural patterns against demographic data to determine what correlations exist and may have some significance. As gateway research, the data collected in the research opens doors to greater opportunities for multi-branch studies that address cognitive load, attention, and other brain-based influences and impacts to learning and mission performance. The data serves to improve understanding of when learning occurs and knowing how to adjust curriculum design to be immediately responsive to performance needs. It acts as a trigger for future research that informs organizational education structures, occupational proficiency, and mission readiness that ultimately enhance wartime readiness under Large-scale Combat Operations.

A Novel Approach to Dynamic Unsupervised Clustering

Christopher Heinlen • Mark Volpi • Randal Allen, Ph.D.

23153

A criticism of Artificial Intelligence and Machine Learning (AI/ML) techniques is brittleness. This means that an AI/ML technique may perform well when analyzing a known data set, but performance will degrade when new data is introduced. While this degradation is apparent when new data belongs to an existing category, degradation is even more pronounced when data from a previously unseen category is introduced. Additionally, many AI/ML solutions do not have a mechanism to detect outliers or noise, instead they force these data points into categories where they do not belong. Despite these weaknesses, our global, digital world necessitates the use of these AI/ML techniques to sift through an ever-expanding data pool.

Dynamic, Unsupervised Clustering by Algorithmic Triangulation (DUCAT) does not fall victim to these shortcomings. It is designed to handle streaming data sets and adds new classification types as new data types are observed. It is not limited to a certain number of categories, and it does not need to be retrained as new data types are introduced. Additionally, it can detect noise and categorize it as such.

This paper will describe DUCAT's process which consists of first comparing new data against known clusters, then searching for new clusters and creating cluster definitions as new clusters are found. DUCAT has been verified by segmenting a dataset of simulated radar pulses into a series of portions which are individually fed into the system. The efficacy of the system is shown by a confusion matrix comparing the DUCAT labels to truth as well as classification cohesion across portions.

This system was developed to classify radar pulses to train operators by highlighting novel signals for education or offloading classification and noise filtering work, but the system can be utilized in scenarios beyond radar classification and this paper will explore alternative applications for DUCAT.

Transforming a Digital World into Real Insights Using Synthetic Data

Javier Garza

23173

In 2022, the value of the global data collection and labeling market was $2.13 billion, with a forecasted value of $12.75 billion by 2030. Driving factors for this trend include Artificial Intelligence (AI) and Machine Learning (ML) advancements, which provide insights to organizations such as the Department of Defense (DoD). When proving out new AI/ML concepts in a DoD environment, a major challenge is the lack of availability of relevant data at an unclassified level. Although large amounts of data are collected and transmitted continuously by DoD platforms, many layers of bureaucracy exist between data and research & development (R&D) organizations that may only have limited budgets and short time-periods to obtain stakeholder buy-in. Even if bureaucratic processes were removed and relevant data were immediately available, the data would most likely be unorganized and formatted incorrectly.

Furthermore, different supervised learning models may have differing input data requirements. Manually labeling and formatting data for each of the chosen models could be necessary, causing delays and cost increases in the development cycle. How can DoD-focused R&D organizations improve this process and ensure that innovation can be accelerated while continuing to abide by data governance policies and procedures?

One solution is to employ synthetic data generation techniques using simulation tools to quickly generate datasets that can be used to train ML models. These techniques enable rapid prototyping and validation of models. The paper will describe the development process for an automatically-labeled synthetic imagery dataset used to train a semantic segmentation ensemble that provides a change detection capability and an instance segmentation model that identifies objects at a pixel level. Additionally, the paper will describe the training process for the models, explain how the trained machine learning models performed with real drone imagery, and finally, describe conclusions about the work regarding applicability to the warfighter.

Unsupervised Clustering for Image Data

Nickolas Vlahopoulos • Spiridon Kasapis • Geng Zhang, Jonathon Smereka

23176

Clustering of image data is the process of sorting images into groups that exhibit similarities. During the clustering process, images are reduced into feature vectors and the statistics of their features are used for placing them into statistically similar groups. Systems that collect images during their operation (e.g. autonomous ground vehicles, satellites, etc.) create large data sets that ideally need to be sorted with minimal human effort. K-means is one of the most widely used methods for automatically sorting images. However, it is heavily influenced by initializations, the most important one being the need to know the number of clusters a priori. In order to overcome the latter shortcoming, validity indices have been used throughout the years to find the optimal number of clusters the data should be separated in. The work presented in this paper comprises an Extension to the Variance Ratio Criterion (E-VRC) that when combined with the K-means can cluster image data of high content variance, without the need to input any information like the number of expected clusters, thus, it operates in an unsupervised manner. Comparisons with other available unsupervised methods (i.e. X-means, U-K-Means, and attractive-repulsive clustering) is discussed in order to demonstrate the superior performance of the new E-VRC method. Several image datasets are used in the comparative studies. The robustness of the E-VRC method is also demonstrated by processing datasets with imbalances in their contents (i.e. many more images from certain clusters compared to the rest clusters) and by processing mixed datasets (i.e. comprised by very diverse types of images). It is demonstrated that the E-VRC does not dependent on initializations, does not care about the data dimensionality nor the content randomness and it is therefore a great tool for efficiently estimating the number of clusters and performing the clustering of image data.

Communication Styles in Human-AI Teams Tasked with Urban Search and Rescue Missions

Ashish Amresh • Nancy Cooke • Adam Fouse • Rahul Salla

23190

Urban search and rescue (US&R) refer to operations conducted in collapsed man-made structures. It has been recognized as a useful domain for studying human-AI interaction. Human-AI teaming in the domain of US&R is a widely researched area, due in part to the complications that arise out of introducing AI into an unpredictable environment such as a collapsed building. In this study we investigate different AI communication styles in a team-based experimental search and rescue scenario. By inviting human participants via a simulated Minecraft based reconstruction of urban search and rescue mission maps, we collect data gathered by incorporating a “Wizard of Oz” design, with the researchers playing the role of an AI advisor, giving guidance to the team of participants during the experiment. The focus areas for the study are the adherence to guidance under different communication styles, usage of the styles, and participants response to these styles. While the objective of the Minecraft based experiment for the participants was to save as many victims trapped in collapsed buildings via fifteen-minute run experiments, this study does not evaluate team performance and instead looks at how teams adhere to the advisor’s guidance, disregard the guidance, and ask for additional information. We present the results of our experiments via two specific guidance conditions (explicit vs information shaping) and modes of communication (voice vs text). Our results indicate that there was a greater adherence with information shaping guidance when compared with explicit guidance and participants seem to respond more to voice over text. The results and discussion presented in this study would help drive the design of human-AI teaming systems especially when the AI’s roles is to provide guidance to human teams.

Large Language Models Have Transformed Our World – Can They Help to Build It?

Graham Long

23206

The extraordinarily rapid and disruptive impact of Large Language Models and their ability to generate human-like, conversational responses to text inputs has revolutionized machine interaction with humans. This step change has stimulated tremendous public attention, debate, controversy, and applied innovation of this artificial intelligence (AI) technology to various industries and purposes, from customer service and language translation to creative writing, content creation, and software development.

The state-of-the-art transformer architectures behind large language models are pushing the boundaries of generative AI, providing new ways of directing AI model behaviour. For example, when combined with diffusion models, they deliver improved methods of creating high-quality content, like synthetic images or 3D models, directly from text input. Generative AI’s ability to create data and content as plausible, synthetic alternatives to real data offers significant flexibility, lower cost, and faster generation of content, data, and synthetic environments. However, although the

capability to create specific AI-generated content may exist, it is the opportunity to incorporate these AI functions into an integrated pipeline that, when combined with AI-based autonomy, has the potential to deliver transformative improvements in efficiency, productivity, and capability.

Current SE pipelines typically employ AI content and data creation processes as independent operations. This paper will build on ongoing research to explore how disruptive AI technologies, like transformer and diffusion architectures together with large language models, may be leveraged and combined with other generative and AI techniques – not only to generate data and content but to provide new, innovative AI-based approaches to directing, integrating and automating these processes. Furthermore, it will consider how these capabilities can be composed into a solution architecture that provides an end-to-end AI-based SE construction pipeline to facilitate the dynamic, faster delivery, and economical production of complex SEs and ultimately enhance their exploitation, user readiness and decision-making.

Automatic Creation of High Fidelity Open Terrain Digital Twins for Off-Road Autonomous Vehicles Training and Validation

Ido Ariav • David Zaphir • Yisachar Shapira • Alon Faraj • Asaf Avinoam

23207

Off-road autonomous vehicles (AVs) are required to operate under extensive uncertainty conditions due to the large variation in natural, unstructured environments. For such AVs, developing and validating perception models based on sophisticated artificial intelligence (AI) algorithms, is extremely challenging. A large amount of reliable annotated data from a variety of diverse environments is required, though acquiring such data can be costly and time-consuming. Off-road environments lack the simulation tool sets, datasets, and algorithms available for urban environments. These limitations can be overcome by using a digital twin for data generation, physical validation, and algorithm testing. However, creating large-scale, high-fidelity digital replicas of open terrain scenarios requires expert intervention, as well as tedious and time-consuming work.

We present a novel algorithm and implementation for the automatic and efficient generation of large-scale, high-fidelity open terrain digital twins. The algorithm relies on standard, publicly available geospatial data, such as 2D raster maps obtained from aerial or satellite images and possibly a digital terrain model (DTM). This algorithm comprises two consecutive processes: first, an AI method converts the geospatial raster map into a material map, where each pixel represents a predefined material (road, soil type, rock, vegetation type, etc.). An automatic pipeline then combines the material map with the raster and DTM to create a simulated environment that is perceptually realistic and geospecific. No specialized graphic design or programming skills are required for these processes.

Our automated pipeline is demonstrated with Unreal Engine 5, although other simulation platforms can also be used. Our results demonstrate that high-fidelity open-terrain digital twins can be generated automatically with minimal human involvement. In rigorous field tests, we demonstrate the applicability of these digital twins for AI training and validation, AV traversability analysis, and more. Finally, we discuss limitations and future work.

AI Inference of Team Effectiveness for Training and Operations

Rob Hyland • Kenneth Lu • Spencer Lynn • Stephen Marotta • James Niehaus, Ph.D. • William Norsworthy • Avi Pfeffer • Curtis Wu • Bryan Loyall

23219

How can we build AI that robustly recognizes how well a team is doing from behavioral data that exhibit the full range of human complexity and dynamics? One method is cognitive inversion. An AI with a causal model of human behavior that is sufficiently dynamic to account for behavioral variability and teammate interactivity and scoped to a set of tasks and interactions of interest, combined with probabilistic program inference, can invert that behavioral model to generate hypothesizes about the underlying goals and causes of observed behavior. As a tutor, coach, or teammate, the AI can then intervene to assist when needed. Here, we describe a prototype prescient, socially intelligent coach (PSI-Coach), a system to perform cognitive inversion, and supporting components. PSI-Coach monitors team members to: recognize their goals, mental states, and behaviors from dynamic streams of actions by combining probabilistic programming inference with a cognitive architecture designed to capture human variation; use those recognized cognitive states to infer team shared mental models and whether they are in alignment or skewed; analyze these goals, mental states, behaviors, and shared mental models to compute practical, real-time team performance indicators; and use all of this information with interactive-narrative technology to plan minimally-intrusive, effective, strategically timed interventions that help to improve team performance. In experiments, we demonstrated PSI-Coach ability to automatically identify team process problems unique to different teams and their situation dynamics, and to provide timely, tailored intervention content that improved team processes within 60 seconds. PSI-Coach showed a 35% increase over two comparison systems' real-time inferences ($p < 0$ .05) and a 42% and 68% increases in agreement with human coaches on interventions over a baseline inference method ($p < 0$ .05). Compared to no-advisor teams, PSI-Coach showed a 60% improvement in aligned-team-priorities ($p=0.09$) and 13% improvement in coordinated-communication ($p=0.09$) compared to baseline trials with no interventions.

On Developing the Intelligent Decision Supporting Technologies for Ground Operations

Sangheun Shim • Kiwoong Park • Dongkuk Ryu • Suhyun Kim • Taejong Lee

23226

The operation concept of future battlefield is shifting toward Mosaic Warefare and Decision Centric Warefare. In this situation, the importance of an intelligent decision support system that conducts battlefield analysis and command decision rapidly and accurately utilizing artificial intelligence (AI) technologies is emerging. That

is, to build an intelligent command and control system, it is necessary to have technologies needed to develop the command decision support using AI. Therefore, to assist in decision-making processes using AI for operations of ground forces, such as infantry and armored units, we are developing techniques to make the AI-Command Decision Support for Future Ground Operations (AICDS). In this paper, the overall concepts and methodologies of our AICDS are suggested. In our AICDS, the Battlefield Digital Twin (BDT) that simulates the battlefield including ground forces and behaviors of both enemies and allies is utilized for realistic battlefield simulation and an AI learning environment. Our AICDS is composed of sequential processes to support command decision at the brigade level for ground operations. First, the enemy threat analysis predicts their behavior and quantifies their threat using deep learning models such as graph neural network (GNN). Second, in the learning environment of BDT, using models such as reinforcement learning, we analyze the optimal assignment/distribution of friendly forces to take action against the analyzed enemy threat. Third, based on analysis results of enemy threat and assigned friendly force, its optimized placement and schedule for firepower are analyzed as part of a course of action. Lastly, operation and visualization tools are developed to support users of our AICDS. Related to these processes and concepts, we suggest developing methodologies, models, and softwares, in addition to experimental results.

Q: Why is this paper important to the community?

A : Our study suggest new concepts and methodologies utilizing AI technologies for supporting military command decision making of ground operations.

Rapid Retraining Architecture for Deploying AI/ML at the Speed of Relevance

Anastacia MacAllister, Ph.D. • Dennis Chen • Victoria Dorn • Arman Ommid • Rey Nicolas • Vasna Khani

23232

Artificial Intelligence (AI) and Machine Learning (ML) investment is exponentially increasing in both the DoD and industry, the DoD requested $130.1 billion in 2023 alone. However, much of this investment goes towards early-stage research and development or proof of concept projects which fail to reach warfighters. Often work in early-stage R&D succumbs to the valley of death due gaps in funding for operationalization of lab proven concepts. One such hurdle often encountered when attempting to operationalize AI/ML models is the lack of end-to-end infrastructure supporting all AI/ML life cycle stages such as development, testing, deployment, and maintenance.

End to end infrastructure is important for AI/ML models due to their unique data needs, however, this necessity is rarely mentioned in literature. Without robust end to end architecture, adeptly tracking and monitoring model parameters and data is often a cumbersome labor-intensive process. This lack of tracking and slow triaging of model performance issues often results in subpar model performance when fielded in operational settings. This paper looks at the critical components required to bridge the R&D valley of death to operationalize AI/ML based on a currently fielded rapid retraining architecture for object recognition. The paper starts by defining and describing three main stages in an end-to-end rapid retraining pipeline: 1) data collection and preprocessing; 2) experimentation and model development; and 3) model deployment and monitoring. From here the paper will cover a use case using the pipeline, showing greater than 25% reductions in model retraining time and increases in model accuracy using a mix of commercial off the shelf (COTS) and custom pipeline tools. Ultimately, work in this paper demonstrates the importance of automating the AI/ML development and deployment process to effectively operationalize this critical new tool for the warfighter.

Training Implications for Future Advanced Air Mobility Operations

Kendall Carmody • Maureen Namukasa • Bhoomin Chauhan • Vivek Sharma • Meredith Carroll, Ph.D.

23247

Advanced air mobility (AAM), of which urban air mobility (UAM) is a subset, signifies an exciting and advanced mode of air transportation that combines novel aircraft configurations with progressive levels of automation to offer convenient and efficient modes of air transportation (Mitchell, 2021). The design of these innovative aircraft will utilize advanced autonomous systems and are proposed to minimize pilot training requirements and scale operations (Mathur, et al., 2019; Feary, 2018). Further, the operational context of AAM will be characterized by low-altitude flights, single pilot operations, unique weather phenomena such as mechanical turbulence, and novel propulsion systems. Early phases of AAM will involve manned flights (FAA, 2020) and as the industry plans for a new era of AAM pilots, there are several considerations for development of training procedures that have distinct differences from traditional aviation contexts. For example, the aircraft being proposed utilize higher levels of automation than current commercial aircraft. While it is being suggested that this will decrease the amount of training required, pilots will need to develop an understanding of the automation functions, which will impact training requirements. Further, the aircraft being proposed have novel technology such as battery-powered propulsion systems. This change from fuel management to battery power management will have implications for training. There will also be changes to various aspects of operations, such as extremely repetitive, short-haul flights, within single-pilot operations with changes to communication with air traffic control. In this paper we will examine key differences between proposed AAM and traditional aviation contexts that have implications for training related to four key areas: (a) automation, (b) the pilot interface, (3) operations, and (4) pilot characteristics. We will highlight key differences between these two aviation contexts, identify implications for how these changes may impact training, and provide considerations for future training development.

Using VR to Validate and Visualize MBSE-Designed Interfaces

Sean Flanagan • Jake Bolton • Hunter Stinson

23250

Several unique challenges arise in the new field of integrations between Model-Based Systems Engineering (MBSE) models

and game-based digital twin visualizations. First, no known standardized interfaces between the MBSE model and game engine visualization are defined, which can lead to custom or stove-piped solutions. Second, the converting and optimizing of CAD-based 3D models into formats sufficient for high-performance game execution can be time consuming. Finally, visualizing digital twin models in true to life scale is insufficient with typical desktop computers and interaction methods can be a challenge. The MB-SimViz prototype, funded by the US Army Program Executive Office (PEO) Aviation, seeks to solve a subset of the challenges.

Progress of the MB-SimViz prototype is covered in the paper. Determining the feasibility and challenges of rapidly visualizing changes to an MBSE model in a 3D game engine is the goal of the prototype. Research was performed to visualize part of an unmanned aerial system ground control station in 3D using the Unity game engine. The Scalable Control Interface (SCI) MBSE model, developed by PEO Aviation, is used to drive the digital twin of the ground control station through a set of virtual reality (VR) controls. Users can visualize, analyze, and test human machine interaction of the 3D models in VR prior to real-world system changes using the prototype. Finally, the recommended interfaces between the MBSE model and 3D engine, lessons learned, and future areas of research are presented in the paper.

Winning Hearts & Tongues: A Polish to Lemko Case Study

Petro Orynycz • Tom Dobry

23264

When minority and local languages are lost, national security suffers: not only are significant increases in substance abuse, suicide, and assault often documented, a void is created that has been historically been exploited by adversaries. For example, tens of millions from minority language communities ahistorically assume the Russian language and/or identity as their own in Ukraine, Belarus, NATO allies, and even the United States. If native language communication gaps remain in the hands of adversaries only, using their long experience with these languages, NATO remains at a major disadvantage attempting to engage these communities. In Europe, psychic wounds inflicted in part by language loss have not been closed by assimilation. Instead, cities experience bursts of isolating tensions in the West and Eastern populations are convinced by adversarial powers that those powers are their true allies, who understand and respect them. Nor is education in the national language a panacea: in the case of Ukraine (and even Spain), non-trivial differences between local lects and the official language create openings for adversaries to fan the flames of separatism.

Using machine translation engines to empower NATO and its partners in training recruits or acting on the ground in the language closest to their hearts and minds can win immediate 'us'-ness and showcase NATO's embraced polycultural vision. In this experiment, custom engines were crafted to translate between the official language of Poland and that of its indigenous Lemko minority, whose language has been subjected to centuries-long hostile power influence and interference. In a first, engines were scored translating from Lemko to Polish using metrics developed with support from DARPA: a bilingual evaluation understudy (BLEU) score of 31.13 and translation edit rate (TER) of 54.10. Meanwhile, in the other direction, the engines scored TER 53.73 and BLEU 29.49, a score 6.5 times better than that of Google Translate's Polish-Ukrainian service.

Leveraging AI to Create Real-time, Character-based Virtual Trainers

Dennis O'Dell, Jr.

23265

Recent advances in Artificial Intelligence (AI) technology have completely redefined the pace of innovation. AI advances are far surpassing even Moore's Law of exponential growth based on Stanford University's findings (Perrault, Raymond, et al. 2019). AI technologies can vastly improve virtual training experiences. Studies show students respond better to character-based Virtual Trainers, which improves effectiveness of online learning (Wang, H., Chignell, M., & Ishizuka, M. 2005). By incorporating advanced algorithms generated by AI to inform the Inverse Kinematics (IK) to realistically animate 2D or 3D characters, Virtual Trainers enhance student learning by simulating movements in real-time rather than using preloaded animation. This real-time capability creates a more engaging experience. Real-time, character-based technology enables a Virtual Trainer to not just instruct a student how to do something, but to show the student how, before the student attempts the task themselves.

The ability to converse in real-time with an interactive agent providing complex and realistic responses is possible via large language models such as OpenAI's GPT-3. By pairing this technology with Voice Recognition and Speech Synthesis, a Virtual Trainer not only physically reacts with a student, but can carry on a conversation, answer questions, and provide tailored instruction. By using Generative AI technology to "Train the Trainer", the Virtual Trainer learns to teach students more effectively based on each interaction. Applied AI technology improves instruction technique to achieve desired learning objectives and can identify struggling students needing more tailored instruction.

AI-enhanced virtual trainers produce effective training solutions benefiting industries from Medicine to Aircraft Maintenance. By making human interaction more realistic in a demanding virtual environment, this technology provides better learning outcomes especially when traditional live training on expensive equipment under demanding conditions is too costly or risky in person.

Developing Methods to Support Social Media Intelligence Analysis

Daniela Miele • Lauren Glenister • Angela Woods

23266

With the recent expansion of social media and the massive outreach these platforms have, the need for social media monitoring has become more important. The specific intent being analysis and sensemaking of actions taken by entities, organizations, and networks that may have the ability to influence narratives or audiences. To achieve this, the Department of Defense (DoD) has made progress in the field concerning analysis of social media intelligence (SOCINT) where intelligence analysts engage in

an iterative sensemaking process, encompassing procedures such as locating, gathering, and organizing data. As a result of these actions, the main goal is to develop schemas and hypotheses that support identification of future courses of actions aiding in mitigation strategies.

Current SOCINT tooling and technologies are geared towards the locating and gathering phases of analysis. These tools work to gathering data related to identified topics from social media platforms such as Twitter, Facebook, and Reddit. However, when it comes to the organization of the data, intelligence analysts often resort to tooling not designed for this phase of analysis, such as Microsoft Word or PowerPoint. This paper will focus on potential ways that sensemaking and schema development can be integrated into SOCINT training and tooling. For example, the implementation of an ontology, or folksonomy for structuring and filtering data, as well as the integration of visualizations to identify patterns among the collected data. The objective of investigating training procedure modifications and enhancements is to evaluate mechanisms that are hypothesized to aid analysts in better formulating schemas and interpreting datasets. As a result of this investigation, tooling tailored to schema development can be provided to encourage proper selection for courses of action and analysis directions.

The Simplification of Complex Systems using Natural Language Processing

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23269

Increased system capability and heavier dependance on software has resulted in systems that are more complex than ever before. This complexity expansion impacts systems engineering analyses throughout the life-cycle of these systems, making system architecting more time consuming. Professional experience and exposure can play a role in the amount of time needed to understand and properly analyze a system, yet increased complexity also increases potential for human error in evaluation and interpretation. Failure to accurately capture system aspects can lead to either system failure or at the very least the accumulation of technical debt. The farther along the system is in its life-cycle, the more difficult it is to correct the issue. Therefore, the success of the system is dependent on the thorough understanding of the various components comprising the system architecture. The authors will present a literature survey highlighting challenges associated with systems architecting and systems engineering for complex software systems-of-systems.

The paper will present the authors' research and progress on an innovative application of Natural Language Processing (NLP) to aid the systems engineer, both in terms of comprehensiveness and effectiveness. We are applying NLP to benefit Systems Engineers, specifically those working in the Model Based Systems Engineering (MBSE) domain. The authors evaluate common NLP techniques that can be applied to the highly technical and systematic written language methods used with MBSE. Our paper will summarize contributions to the technical literature in this innovative application of NLP for MBSE. We will present a use case application study of the implementation of NLP to provide traceability between a proposed product architecture and a standard for compliance.

Continuous Asymmetric Risk Analysis: A New Method to Analyze Risk

Zachry Engel, Ph.D. • Nickalus Harrill • Jacob Ediger • Nicolas Velez Camacho • Randal Allen, Ph.D.

23270

The current Risk Reporting Matrix used by the Department of Defense is a useful tool for determining the risk associated with an action, but it's limited due to the discrete nature of the metric. Currently, the Risk Reporting Matrix is built using two Likert Scales, one for the likelihood of the event, and one for its consequence. This gives the user 25 possibilities for a likelihood-consequence combination. While this gives a concise and easy to understand answer, it does not fully inform the user of the true risk level for the decision.

Continuous Asymmetric Risk Assessment (CARA) alleviates this shortcoming by transforming the discrete risk matrix to a continuous gradient field. It is designed to provide the user with infinite combinations of likelihood and consequence which more accurately describe the risk associated with the decision in question. Furthermore, by leveraging the use of asymmetric Gaussian distributions, CARA creates confidence intervals around nominal risk, displaying likely outcomes and its variation.

This paper will describe how CARA identifies risk and creates asymmetric confidence intervals by evaluating a real risk data. The data evaluated in this paper was used to demonstrate to the owner of the data how decisions will impact the risk of their decisions. This paper will also demonstrate how the risk level and variability is reduced as mitigation and prevention steps are added, which leads to more accurate and descriptive risk analysis over a continuum.

Enabling Agile Authorization for Mixed Reality Training Applications and Devices

Brandi Pickett • Jason Ingalls

23274

Accelerating technical training, equipping and empowering Airmen for the battlespace is a strategic goal for the Air Force. Commands, Wings, and Users want to leverage training applications coupled with mixed reality devices as it saves training time, makes it more accessible, and saves costs. However, training applications and devices are delayed for operational use due to the navigating the inscrutable Authorization to Operate (ATO) process.

The DoD adopted the Risk Management Framework (RMF) to empower services to assess, manage, and validate cybersecurity risks. The RMF process is directed to be used for DoD Assessment and Authorization (A&A) processes. However, these processes are exhaustive, resource-intensive, requiring a sophisticated skillset, and often not considered until the application is ready to deploy, significantly delaying timely delivery of today's technology to the warfighter. In fact, RMF implementation can take a year or longer for an application to get an ATO. This creates significant problems with industry costs and effective risk management.

The military member responsible for performing the A&A activities must accomplish the mysterious ATO process without the training and experience needed to achieve success while tackling the many misconceptions, fallacies, and esoteric rules.

DoD must shift from a cybersecurity "snapshot in time" and paper drill compliance culture to a culture where automation is tightly coupled with real-time continuous risk monitoring.

Thought leaders have expressed ways in which to combat the A&A challenges. An analysis of these processes is necessary to identify the best approaches to enable agile authorization.

Innovative solutions that enable real time risk management must reduce lead time for compliance by assessing applications with an agile, DevSecOps approach, and marginalize the labor and financial costs for obtaining an ATO.

Enabling the Human Dimension in Joint All Domain Command and Control (JADC2)

Emilie Reitz • Kevin Seavey • Samuel Chambers • Justin Wright

23283

The ongoing development and fielding of Joint All Domain Command and Control (JADC2) capabilities will change how joint and coalition forces operate, providing new capabilities to sense, make sense and act across all domains and phases of war, hand in hand with our mission partners. JADC2 technology advances will require commensurate changes in doctrine and the way warfighters conduct C2. Accordingly, JADC2 will require changes in how we educate and train warfighters – or we will create a situation where undertrained users employ new systems in old ways, to the detriment of mission accomplishment. To this end, training and exercises supported by simulation and simulators must be able to support the advanced C2 aspects of operations during crises and conflicts with peer competitors. The institutional structure to push JADC2 training exists in Joint Staff J7's Joint Live, Virtual, and Constructive (JLVC) Federation. JLVC is a collection of Service and Agency models and simulations using DoD authoritative data and standards integrated and distributed via JS J7 tools and networks. The ongoing modernization of JLVC presents an opportunity for J6 and J7 to drive JADC2 capability development and shape the way training happens in a JADC2-enabled environment.

This paper will outline ongoing work within the Joint Staff to train warfighters to use JADC2 capabilities. The joint community must work with nations and Services to demonstrate and assess C2 systems in a contextualized environment supporting JADC2 systems and operational concepts. This requires end-to-end, "big data" simulation that integrates actions from the global level to the tactical domain, representing all Services, participating mission partners, and new threats.

Analyzing, Preparing, and Processing Input Geospatial Data for High-Resolution Terrain Generation

Tu Lam • Matt Reilly • Pedro Ramos • Hunter York • Clayton Burford • Scot Shiflett • Amanda Larrieu

23287

Automatic generation of high-quality terrain data for use in military training applications (especially, integrated Live-Virtual Training) depends heavily on gathering and acquiring high-quality and high-resolution data from a variety of appropriate sources. One of the more accessible sources today comes from images collected by drones. Using photogrammetry, the images are often post-processed to produce detailed 3D representations of the environment. Starting the data generation process with clean data substantially reduces the need to remove anomalies or to perform unnecessary processing further in the terrain database generation pipeline. Unfortunately, quality data is not always provided or available. High resolution collection sources often produce outputs that include inaccuracies, errors, or suboptimal content. The increase in resolution also adds to the challenges in discerning between accurate and erroneous aspects of data. Recent collections also highlight the need for more sophisticated geometric analysis methods and tools to detect and remove anomalies that are geometrically joined with or close to good data. Therefore, the input data must be further analyzed, cleaned/corrected, and prepared to make it usable in the terrain generation process. This paper describes some of the key techniques and the analysis process used to (a) improve the collection process and ensure data collection approaches yield the highest quality data possible, (b) leverage AI/ML techniques to detect, then fix (or at least reduce) anomalies in suboptimal input/collected data before the data is further propagated through the pipeline, and (c) combine both AI/ML and non-AI/ML automation to extract the desired content needed in generating high-resolution terrain data.

Refugee Flow Management and Resilience Implications

Kostadin Lazarov • Orlin Nikolov

23291

The article is focused on the large masses of people movement. It is witnessed as permanent and natural event in human history. It is related with another big scale events like disasters or crisis (including any kind of military operation). Some tasks are set in the research like: definition of set of parameters correlated with the large masses of people movement, definition of the coefficients elaborating the large masses of people movement mathematical model, AI data processing. The research target full spectrum outcomes – from abstract like the large masses of people movement model to the application for flow management.

Learning and Emotional Outcomes in an Immersive Omnidirectional Pilot Study

Fred Martin, Jr. • Maria Harrington

23294

The U.S. Army's Synthetic Training Environment (STE) capability development invites questions such as whether infantry Soldiers would benefit from more immersive simulation-based training capabilities. Results from an empirical mixed methods pilot study suggest the impact of combined immersion and embodiment positively influence learning gains. The study showed learning gains and emotional outcomes. The between-subject design experiment included 15 participants randomly assigned to one of three system configurations. Each configuration gradually increased immersion and embodiment as combined system features. The control condition was a desktop configuration, while the experimental conditions included a Virtual Reality headset (VR) configuration, and a novel configuration using an omnidirectional treadmill with a VR headset enabling full-body virtual environment (VE) exploration. Each condition accessed the same realistically modeled geospatial VE and learning content and completed the same VE-interaction measurement instruments. The pre-test included declarative information-focused questions or complicated tasks, while the post-test repeated the pre-test and included a situational awareness measurement or complex task requiring participants to draw a sketch map. Learning gains occurred in all three conditions, however, statistical tests revealed no significant differences between conditions. There were significant strong positive correlations between increased immersion-embodiment levels and emotional factors which contribute to learning. Reviewing graphical depictions combined with quantitative and qualitative data highlighted patterns worth noting. Patterns suggest learning task type interacts with system configuration. Increased immersion levels, increase subjective feelings of presence and immersion, and higher feelings of immersion are significantly and strongly correlated to emotional outcomes viewed as important for long-term memory retention. A larger sample is required for increased statistical power to determine the significance of identified differences. These results may inform Army senior leaders about the educational/training capabilities of immersive-embodied simulations for improved related decision-making.

Scaling Intelligent Agent Combat Behaviors Through Hierarchical Reinforcement Learning

LtCol Scotty Black, USMC

23302

Remaining competitive in future conflicts with technologically-advanced competitors requires us to accelerate our research and development in artificial intelligence (AI) for wargaming. More importantly, leveraging machine learning for intelligent combat behavior development will be key to one day achieving superhuman performance in this domain—elevating the quality and accelerating the speed of our decisions in future wars. Although deep reinforcement learning (RL) continues to show promising results in intelligent agent behavior development in games, it has yet to perform at or above the human level in the long-horizon, complex tasks typically found in combat modeling and simulation. Capitalizing on the proven potential of RL and recent successes of hierarchical reinforcement learning (HRL), our research is investigating and extending the use of HRL to create intelligent agents capable of performing effectively in these large and complex simulation environments. Our ultimate goal is to develop an agent capable of superhuman performance that could then serve as an AI advisor to military planners and decision makers. This research is primarily divided into five research areas aimed at managing the exponential growth of computations that have thus far limited the use of AI in combat simulations: (1) developing an HRL agent architecture for combat units; (2) developing a scalable HRL training framework for agents; (3) developing space-invariant state and action abstractions to manage the exponential growth of computations; (4) developing hybrid AI behavior models that leverage RL, expert systems, and game theory techniques; and (5) implementing our HRL agent architecture and training framework into both a low-fidelity and a high-fidelity combat simulation. This research will further the ongoing Department of Defense's research interest in scaling AI to deal with large and complex military scenarios in support of wargaming for concept development, education, and analysis.

Using AI to Increase Trust in AI - Yes, We're Serious

Kyle Russell • Connor Green • Charles Etheredge • Michael Yohe • William Marx, Ph.D. • CAPT Timothy Hill, USN (Ret.) • Lt Col Robert Odom, USAF (Ret.) • Col Daron Drown, USAF (Ret.)

23316

The use of Artificial Intelligence (AI) in high-consequence decision-making tasks presents legal, moral, and ethical challenges. Complicating the issue, AI systems have become more complex and are less explainable than deterministic or rules-based systems. AI agent behaviors are viewed as "black boxes", as their decisions can seem arbitrary or opaque to users, and in some cases, even for the developers of the system. Additionally, algorithmic performance is not guaranteed as complexity and number of inputs grows so does the difficulty in covering all corner cases. This lack of trust has significant negative consequences for the adoption of AI in decision-making.

To remedy this, the trust gap must be addressed by adapting the systems of verification and validation (V&V) used for military technologies, particularly the Test and Evaluation (T&E) capabilities. This includes developing individual testable metrics from contract requirements. This requires breaking apart functionality into small testable elements, with objective figures of merit, to make incremental improvements.

To advance the state-of-the art in establishing trust in AI for complex aerospace systems, we propose an approach we call "Digital Neurology" that can provide a real-time in-situ, trained, observer "agent" that can monitor and evaluate AI-based Neural Networks (NN). Our paper will describe our concept for experimentation with autonomous aircraft. The observation agent would observe and infer behaviors that are indicative of:

- Normal and abnormal computational processing
- Anticipated and unexpected situations
- Regions of high and low computational use

- Regions of importance and insignificance

Similar to a human instructor following a human pilot through the training experience, our AI observer agent will be deployed with the autonomous aircraft systems, following and learning behavior to build trust. Our paper will include a scientific literature survey and will detail our scientific contributions associated with advancing trust in AI for autonomous aircraft.

Finding Critical Areas of Concern for sUAS Collision Avoidance

Elijah Keck • Mustafa Akbas

23354

This paper aims to provide a methodology using both agent-based simulation and also game engine-based simulation to find critical areas of concern regarding the FAA right-of-way (RoW) rules as they apply to interactions between small unmanned aerial systems (sUAS) and other unmanned aerial systems (UAS) or manned aircraft. Avoiding collisions between sUAS, other sUAS, or manned aircraft is crucial for advancing safety and security of all flight and our airspace. While modern sUAS have collision avoidance on board, these must be based on the RoW rules developed by the FAA. The specificity and growing use of sUAS may cause these RoW rules to be insufficient in avoiding collisions. As sUAS are used increasingly, airspace encounters between sUAS and UAS or manned aircraft become more common and provide the opportunity for scenarios in which the RoW rules may be insufficient or unclear. This is especially important in interactions between sUAS and manned aircraft. Due to the possibility for injury or loss of life in those interactions, new methods to validate sUAS conflict resolution must be developed. The approach we propose uses a combination of an agent-based simulator, Anylogic, and a higher-fidelity game-engine based simulator, AIRSIM, to simulate encounters. This approach is efficient and modular to determine scenarios that may need closer examination within a reasonable amount of time and test different types of collision avoidance algorithms and aircraft. These simulations iterate through different encounter scenarios and manipulate encounter parameters such as speed, altitude, and heading for each encounter. Simulations are first run in Anylogic. Any iterations where the actors collided or had a near miss are then identified. These iterations are then run in AIRSIM's higher fidelity simulation. The results of these AIRSIM simulations are used to indicate critical areas of concern that necessitate real-life flight tests.

Novel Schedule Forecasting for Low-Volume Highly-Complex New Product Development

Bruce Chehroudi, Ph.D. • Jonathan Lam, Ph.D. • Gus Benavides • Scott Morchower

23364

A novel schedule forecasting methodology (named Nostradamus) was envisioned/tested for low-volume, highly-complex, new product development (NPD) projects to contribute towards managing risk of a unique, large-scale program. The goal was to offer objective real-data based product-delivery schedule forecasts with acceptably high precision. Nostradamus is designed to combine "past (most recent) manufacturing performance" of a manufacturer (or project management firm) with "current information" from the products that are presently under manufacturing, to provide an objective delivery date (or project completion date) forecasts for not-yet-delivered products. The past information used, conforms with the "reference class concept" described by Nobel Prize laureate Daniel Kahneman and coworkers, and possesses the highest similarity to products under manufacturing, for which schedule forecasting is required. Additionally, the Nostradamus software program ranks a list of components of the products that are heavily affecting the delivery dates, or delivery delays. Hence, targeted measures can be taken to favorably affect the product delivery dates and reduce the schedule risk. The product's major components (or tasks), along with their expected completion dates (ECDs), both defined/determined by the manufacturer, constitute the "current information" and are provided by the manufacturer at each Program Management Review event. This set of product components, along with their ECDs and manufacturer's estimated product delivery date, collectively define the Line-of-Balance (LOB) information. The "Accuracy Level" probability distribution function (PDF) of the ECDs is defined and calculated for a most recently delivered product and then utilized in a subsequent Monte Carlo simulation that used the "current information," generating a product delivery failure probability (DFP) graph. This DFP was used to find delivery date forecast at any probability level. Results of the tests indicated that, over the project duration, a time-averaged forecast imprecision value of -5% was achieved for Nostradamus, as compared to 140% by the manufacturer.

Hyper-Concurrency: The Convergence of Development, Test, and Training

Joshua Fields • Timothy Mobeck • Trevor Rossi • Craig Smith • Jason Valestin

23366

Managing the differences between training systems and the platforms they simulate is a persistent engineering and acquisition challenge. Training system deployments often trail production systems, sometimes by years, due to underlying differences between the two. This delay prevents training operators on deployed system configurations. To move at the speed of relevance, it becomes critical to create new development and deployment strategies that minimize the gaps between training and production systems. This paper describes the concept of Hyper-Concurrency in the development and deployment of simulation systems. Hyper-Concurrency is the state of deploying working software to both platforms and training systems simultaneously. Hyper-Concurrency is attainable by converging development, test, and training environments. To achieve Hyper-Concurrency, software development architectures for platforms must include provisions for training systems from the start. By using modern software architectures, applying lessons from ARINC-610, and leveraging advanced simulation, applications can be built for multiple targets simultaneously, tested in high-fidelity simulation environments that replicate the operational domain of the System Under Test (SUT), and deployed to training systems alongside production deployments. Integration of DevSecOps and Digital Engineering Environments enables automation and ensures integrity of the

development process. Implementing ARINC-610 functions during aircraft systems development and using simulation technology from the training industry within virtual test environments reduces both the need for costly and slow rehosting activities as well as development cycle times by enabling rapid integration and automated test for the SUT.

Creating effective and sustainable solutions requires Hyper-Concurrency as it results in faster training and fewer wasted resources in production and procurement, particularly with multi-domain systems. Complex operational environments necessitate new paradigms and methods that are orthogonal to the traditional development process, leveraging re-use across the entire lifecycle, reducing duplication and waste, creating a sustainable development environment that facilitates rapid hyper-concurrent delivery.

Virtualized Simulation for Military Concept Development and Experimentation: The Cerebro Battle Lab, a Case Study

Dirk oude Egbrink • Jan Jaap Knobbout • Zeeger Lubsen

23372

In recent years, virtualization technologies have become standard practice in many industries, mainly due to their ability to provide a flexible computing environment at a fraction of the cost and time required for traditional approaches. This paper presents a case study of a unique application of virtualization in the military domain, specifically in the area of concept development and experimentation (CD&E). The Netherlands Aerospace Centre has invested in the development of a virtualized facility, called the Cerebro battle lab, to support research into new military concepts and the simulation of large-scale scenarios for the Netherlands Armed Forces. The authors describe the design and implementation of the battle lab that hosts various types of simulation software, including research flight simulators and CGF simulation tools, on virtual machines in a secure vSphere server infrastructure. This allows operators and researchers to run simulations and experiments in a controlled and repeatable manner, while providing greater flexibility and scalability compared to alternative methods, like standard desktops or keyboard-video-mouse (KVM) setups. This paper also describes the trade-off analysis that led to the decision to use a virtual desktop infrastructure (VDI), as well as the technical aspects of implementing a VDI with low-latency and graphics-intensive requirements, and the operational benefits and challenges encountered during use. This case study provides valuable insights for anyone who is interested in the virtualization of simulation systems in the military and defense industry, especially those looking to implement similar solutions in their own organizations.

Genetic Algorithms for Wargame Operational Planning

John Pav • Adam Haywood • Eric Jamieson

23373

Assigning weapons to targets is a key aspect of operational planning in wargames. In past wargames, these assignments were built by subject matter experts with a deep understanding of each weapon system, platform, and target. However, the time-consuming process of manually building an Integrated Tasking Order (ITO) creates a strain on the game-move process. To adapt to increasing demand for speed and effectiveness, A.I. methods to automate the assignments must be explored. It is a classic example of the Weapon Target Assignment Problem (WTAP[BM[1]) in which a set of various weapons is assigned to a set of targets to maximize damage to the enemy. The WTAP can be modeled and defined using tactical and logistical constraints, including platforms' and munitions' compatibility, availability, lethality, and range. This paper describes a customized genetic algorithm (GA) and demonstrates its ability to solve for a feasible weapon-to-target operational plan. Due to the vast solution space of all possible assignments, finding an optimal solution is computationally expensive, but in a fast-paced wargaming environment, the need for rapid results is imperative. Empirical testing of this genetic algorithm on the problem proves its capability to obtain an effective ITO quickly. We simulate the attacks planned in the ITO using Monte Carlo and analyze the performance by comparing the attack results at various levels of GA convergence. Furthermore, optimizing ITOs in each successive move leads to efficient utilization of in-game resources and more damage to targets over the course of the game.

Digital Twin Approach for 3D Visualization and Optimization of 5G Non-Terrestrial Network

Chuan Pham • Maroua Ben-Attia • Abdo Shabah • Kaniz Mahdi • Jaroslav Holiš

23377

The autonomous systems field, including UAVs, HAPs, and satellites, has rapidly expanded in recent years. As such, 3D visualization in a 3D environment is a promising method for visualizing networking in autonomous systems to improve management and monitoring.

Our research proposes a digital twin solution for Munich that uses 3D visualization, network virtualization, and machine learning algorithms to simulate and optimize the behavior of the city's network functions and radio functions. We begin by describing the fundamentals of digital twin technology and model a resource orchestration problem to optimize the network performance of non-standalone (NSA) 5G from user equipment to the core network. We then examine the specific challenges faced by Munich in managing its network functions and radio functions. Our solution utilizes 3D visualization to provide an immersive and comprehensive view of the city's network functions and radio functions, allowing operators to quickly identify and address issues. Optimization and machine learning algorithms analyze the network data to optimize performance and provide real-time recommendations to prevent failures and operate the networks. We validate our approach's performance and discuss its potential impact on Munich, including improved network performance, better resource management, and increased efficiency and safety. We also highlight its potential application in disaster situations, inspired by the data based on Munich floods of July 2021. Overall, we argue that using a digital twin approach to virtualize network functions and radio functions within a 3D simulation has significant potential to enhance

network management and optimization. The Munich case study demonstrates the feasibility and potential benefits of this approach for other cities facing similar challenges.

Crowdsensing of Meteorological Data for Safety and Efficiency of Unmanned Aerial Traffic in Urban Environment

Jose Alejandro Gonzalez Nunez • Mustafa Akbas

23382

Advancements in the area of unmanned aerial vehicles (UAVs) are expected to result in an increase in flights being conducted in urban areas. However, the presence of buildings with varying sizes and the dynamic conditions in urban areas generate stark differences in environmental conditions that UAVs operate such as the wind, temperature, pressure, and humidity across a city. These changes in meteorological conditions can be significant for the operation of UAVs even across short distances. Smaller UAVs find themselves more susceptible to any variations in weather which can cause substantial challenges in flights due to their lower weight. This challenge requires a method to continuously collect reliable meteorological data at multiple points across cities. This paper proposes the use of crowdsensing and agent-based modeling for high-resolution spatial and temporal data collection in three dimensions (3D) and predictive performance improvement for UAV operations in urban areas. This approach uses an agent-based model to simulate a 3D urban environment where we use a game-theory based crowdsensing model to collect data from multiple agents across the city. The simulation aims to find a solution to the research challenge that provides consistent spatial and temporal weather data for creating a 3D weather map of urban environments. This data will allow us to assess the safety and efficiency of a planned flight route as well as suggest alternative paths that can allow the vehicle to safely reach its destination.

Real-time Updated Digital Twins for Drone Swarm Command and Control

Berk Cetinsaya • Carsten Neumann • Dirk Reiners • Carolina Cruz-Neira

23384

Drones are changing the face of warfighting more than any other technology in the recent past. They keep getting smaller, cheaper, and easier to deploy, however, as more and more drones are deployed, analyzing, and integrating their data is becoming a major problem. Turning a screen of 20 or more video feeds into an operational picture and creating situational awareness is an incredibly difficult task for commanders to be effective leaders.

The goal of this work is to replace the wall of video feeds with an integrated Digital Twin (DT) of the real world that is being observed by drones. A 3D model is created through LIDAR scans or photogrammetric reconstruction. This 3D model is updated in real-time, based on the video feeds from the drones. We explore different levels of detail for the updates, based only on video and/or 3D reconstruction.

As we are updating the visual representation programmatically, we can also use it to solve the second major problem of drone swarms: control. Drones usually require a pilot per drone, which doesn't scale to large swarms. In our case, we can keep track of when any part of the Digital Twin was last updated, and after finding the least up-to-date part, we can task a drone to update it, and therefore automatically keep the Digital Twin as up-to-date as possible. This allows control of an arbitrary number of drones without manual intervention.

We demonstrate the feasibility of these approaches in a simulated environment using virtual drones observing an animated virtual world. The results show the potential and power of our proposed methods.

This approach has the potential to significantly improve the safety, efficiency, and reliability of physical systems and applications in military operations, disaster recovery, search and rescue operations, safety and emergency training, and other areas.

Joint Data Mesh – A Data-Centric Approach for Modeling & Simulations

Samuel Chambers • Walter Cedeño • Jay Freeman • Colby McAlexander

23406

The Joint Live Virtual Constructive (JLVC) federation has evolved for the past 20+ years to meet mission needs for Joint Training. The 2022 National Defense Strategy calls for a revolutionary approach to integrate data and software to speed their delivery to the warfighter. There is a need to rapidly provide realistic experimentation, rehearsal, and training to the Joint Force. In addition, DoD directives for data analytics and implementation of a zero trust architecture (ZTA) are forcing modernization across the Joint Training Enterprise. The JLVC is modernizing to enable faster integration of Service, agency, and partner simulations. While modernization is necessary, it should build on the established governance processes and standards that have enabled the existing JLVC to support a steadily increasing number of joint and service training events.

The vast amounts of data that are currently required to support the design, planning, and execution of events should align with authoritative data sources, and enable analytics to inform concept development. To maintain an operational advantage over adversaries, the DoD has defined a data strategy based on treating data as a strategic resource central to all warfighting levels. Valuable data generated during a Joint Event Lifecycle should be processed into usable information and made available efficiently and at scale.

This paper presents a conceptual architecture that incorporates modern data mesh principles while building on the existing foundations of the JLVC federation. This approach uses the concepts of unity of effort and treating data as a product to provide the necessary level of coordination and cooperation to work towards common objectives. Adding a self-service infrastructure with the consistency provided by an ontology provides the agility and flexibility to quickly enable the use of the authoritative data while supporting future data analytics at both speed and scale.

Model Mining in Sensor Data for Rapid Terrain Analysis

Frido Kuijper • Ruben Smelik • Ewan Demeur • Remco van der Meer • Vera Bekkers

23408

Military simulation applications put strong requirements on terrain modelling. Large mission and training areas need to be represented in detail, while users expect these models to be available at ever shorter lead times. Capabilities are needed that rapidly transform sensor data into models that fully represent the complexity of the mission environment. Industry seems to have solved part of the problem with mature photogrammetric techniques and LiDAR data acquisition. However, the data delivered by these techniques is often limited to a geometric and only visual model that has little semantics and as such is not ready for simulation.

Current sensor data analysis techniques result in labeled imagery and point clouds, assigning semantics to pixels and points. At best, the points are then converted into semantic linears or areals. The challenge is to find complete models that match with the geometry and semantics of the points. The research presented in this paper addresses this challenge. We seek techniques that directly extract semantically rich and simulation-ready models from sensor data. Our hypothesis is that procedural modelling techniques are key to the solution and that innovative application of modern data analysis techniques is required to delve instances of these procedural models from the sensor data. We introduce the concept of model mining to refer to the process that finds these models by fitting optimized models to sensor data.

In our paper we report on results we have achieved with model mining applied to a drone based point cloud dataset. We use particle swarming optimization techniques to find procedural models within the data. Model mining is a complex problem that needs extensive research to mature. We hope this paper will trigger others to take the challenge of model mining and bring rapid terrain analysis to the military simulation community.

Using AI and Neuroscience in Immersive 3D Flight Simulation Device to Accelerate Pilot Training

Jean-Francois Delisle

23412

To improve and accelerate pilot training, this paper explores the capture of cognitive/psychophysiological states using biometric sensors and flight telemetry to drive an intelligent human performance assessment system in immersive 3D flight simulation device.

Assessing pilot performance during a training session is a capability that can partially be performed by an AI-based algorithm. With technical data gathered during a flight maneuver, such assessment can provide objectivity during flight training, can be a predictor of future pilot performance, and adapt simulation training using a combination of flight telemetry (technical skills) and biometric/behavioral data (non-technical skills).

Evaluation of non-technical skills remains difficult without the support of data analytics and proper visualization tools. Additionally, soft skills are inherently more difficult to grade compared to technical performance. An AI engine can provide cues on behaviors and cognitive/psychophysiological states that cannot be easily observed by the instructor.

With a cohort of 16 novices, we explored neuroscience capabilities that could enable real-time adaptive flight training using a variety of data collected from a flight training session. By using electroencephalogram (EEG), eye tracking device and flight telemetry data with N-Back, BART & IGT cognitive baseline methodologies in a fast-jet flight simulator with an e-Series Medallion visual, we intend to provide a training scenario & maneuver analysis during initial training for both technical and non-technical flight performance.

Creating Robust Evolvable MSaaS Services: An Integrated Model-Driven Engineering Approach

Chris McGroarty • Scott Gallant • Keith Snively • Herwig Mannaert • Alexander Boucquey • Christopher Metevier

23413

The North Atlantic Treaty Organization (NATO) Modelling and Simulation (M&S) Group (MSG) is currently working towards the specification and development of an M&S as a Service (MSaaS) platform for supporting training and experimentation. The United States Army Combat Capabilities Development Command - Soldier Center (DEVCOM SC) Simulation and Training Technology Center (STTC) and developers of the Normalized Systems eXpanders Factory (NSX bv) have developed a model-driven engineering approach for generating M&S services within the NATO MSaaS environment that is compatible with the High Level Architecture (HLA) distributed simulation standard. The generation of software from conceptual models for simulation logic and data aims to provide consistent model implementations across simulation systems, to improve configuration management, and to reduce the software development cost.

In this contribution, we present this integrated model-driven approach that leverages two generative programming tools. At the level of individual simulations, the STTC Generative Programming (GenProg) tool captures models in a Domain Specific Language (DSL), which allows model authors to specify model inputs, outputs, and logic, as well as test and generate the models in various programming languages and simulation architectures. At the federate level of the HLA, the Normalized Systems (NS) code generation tool enables the definition of the HLA objects and interactions of the Federate Object Model, to generate the interoperability classes needed to interact through the Runtime Infrastructure, and to expose the simulation service. Together, these tools generate full M&S services from model definitions for deployment within the NATO MSaaS environment, remaining agnostic with respect to specific technologies. We furthermore present details of an implementation prototype, featuring the generation of simulation services based on GenProg and NS models, while highlighting the advantages and current limitations of the approach, as we aim to help realize the concept of MSaaS.

Force Design Using AI, Digital Engineering, and Wargaming: Sports Insights

Matthew Bowler • Joshua Traub • Brian Hall

23416

Military force structure analysis is complex and decisions can take a substantial amount of time and resources to operationalize and possibly more to change (Murphy, 2014). However, modern warfare is characterized by rapid adaptability to competition. The reconciliation of these differences can be aided by Artificial Intelligence (A.I.). While much research has been put into developing A.I. agents capable of winning games, this paper focuses on applying A.I. to system-of-systems level decision making (Robertson, 2014). By looking at how professionals in sporting use A.I. in games to assess component level contributions to success, this paper lays out how Digital Engineering and Wargaming can be used to train an A.I. model that can optimize force structure and prepositioning decisions across conflicts. Sports and military competitions both require various members of a team to work together to complete their collective objectives and overcome opposing teams. Like force structure and prepositioning of assets for military conflicts, sports teams need to determine their formation and lineup. This paper proposes using MagicDraw's model-based systems engineering capabilities to flexibly model force structures and mission threads. With this digital environment, data capture and force restructuring in Wargames are scalable and accessible to A.I. systems (Mittal, 2022). Wargames will be used to generate vignettes and outcome data to train the A.I. (Lingel, 2021). Emergent properties and other confounding variables make it challenging to determine what makes a certain lineup or formation better than another (O'Connor 1994). However, the A.I. model described in this paper can elucidate the impact of any individual attribute to a team's overall success in competition. In sports, there is an extensive history of game outcomes and performance data which is crucial for training A.I. algorithms. This paper will demonstrate how, by learning from Wargames, A.I. can optimize force structure and prepositioning decisions.

How Are You Enabling Model Reuse and Development for Simulation?

Chris McGroarty • Scott Gallant • Keith Snively • Christopher Metevier • Anup Raval • Greg Tracy • Mark Schlottke

23420

Truly enabling model reuse and development continues to be a challenge across the US Department of Defense. The US Army Combat Capabilities Development Command Soldier Center (DEVCOM SC) has embarked on a research effort to: 1) further the state-of-the-art in capturing model definitions in a model-developer user friendly manner; while, 2) future-proofing by creating the capability to code generate into any simulation environment. The resultant Generative Programming research project consists of three major thrusts: the authoring of models, the domain specific language (DSL) to capture the model, and the code generation of a model into executable simulation software. As part of the technology maturation process, numerous physical models have been represented and subsequently code generated to numerous simulation systems demonstrating the capability. As the research scope expands, the effort has embarked on behavior modeling and code generation of M&S as a Service (MSaaS) implementations to further prove out the technology.

This paper details emerging results from this Generative Programming research project. These results included several areas to improve model authoring, including real-time validation and error checking, and batch refresh of imported models. Other results included updates to the generation capability, including the generation of MSaaS applications and web-enabled services. Finally, the project tackled challenges through research into exploring DSL enhancements into how behavior representations can be defined, and code generated to support a variety of simulations. From these results, the paper details several valuable lessons identified for model authoring with respect to the real-time testing and debugging of models, as well as the need for a platform that better supports model language experimentation in order to incorporate behavioral models. Ultimately, we offer a glimpse into the future of model reuse for military simulation by taking advantage of the latest advances in computer science to further the art of simulation.

Blockchain Cybersecurity for Edge Computing Nodes such as Digital Twin, and Other Deployed Edge Systems

Michael Wikan • Yugandhar Cindepalle

23434

In the current cyber threat environment forces must swiftly modernize their approach to cyber defense hardening vulnerabilities using rapidly deployable low-cost solutions. With recent advances by potential adversary entities in Quantum Computing, it becomes even more imperative to harden these points of attack against cyber intrusion. To achieve this logistical security, our paper describes how Blockchain can be deployed to Edge Systems as a means of degrading adversary efforts to find weaknesses in both our first responders and their logistical support via Digital Twin modeling.

Blockchain technologies allow the compartmentalization of data that deters or rapidly degrades the ability of an adversary to destabilize our response capabilities. Edge computing, integrated with blockchain, enables distributed and secure edge computing that can promote the integrity of IoT data. The IoT architecture is divided into three layers: An IoT device layer, an edge layer, and a cloud layer. Blockchain can be integrated at each of these layers. Communication between IoT devices, between devices and the edge server, or between edge servers is recorded as transactions and stored on the edge server blockchain. Edge servers process real-time requests and store data in their blockchain. Data that is not time-sensitive and needs further aggregation or analysis is sent to the cloud layer.

This paper explores the validity of Blockchain deployment within law enforcement and digital twin-supported environments, its "friendliness" with existing Edge Compute systems as well as those in development and details the advantages of deployment vis-a-vis potential adversary, cyberattacks that the U.S. Forces will be facing soon or are already facing. This review of the utility

of this Blockchain integration can provide a roadmap for tools to rapidly increase the defensibility of our forces both at home and in the field.

Real-time Analytics to Support Operational Decision Making

Dejan Neskovic • Jerry Sheehan • Alec "AJ" Gray, Jr.

23437

In the current global threat environment, Homeland security depends on both domain and situational awareness. The probability of a secure homeland is based on conditional probabilities describing the domain and situational awareness. These probabilities increase with the ability to deploy and utilize powerful data-driven models that make sense of the large volume of information available. With data continuing to grow in scope and complexity, organizations require innovative strategies, services, and technologies to unlock the value of their data analytics potential. Data can be used to make more insightful, forward-looking decisions about readiness, logistics, personnel, intelligence, and a host of other critical mission concerns.

The use of highly skilled technological capabilities coupled with a new generation of advanced predictive analytics offers government organizations the opportunity to take advantage of one of their most valuable resources, data, and then turn that data into action.

Our paper describes our approach for building predictive models using predictive analytics supporting faster and better critical decision making, using a set of modern machine learning operations (MLOps) best practices geared to help a user fulfill its various missions and can easily adapt to accommodate changes in mission priorities. A direct result of predictive model research is providing real-time predictive analytics to decision-makers for faster and better models. This is achieved via a suite of deployed predictive models, which are trained and continuously improved using open-source custom AI/ML pipelines utilizing supervised and deep model learning on large and varied data sets. The models could also be used as stand-alone tools to predict future trends/events and provide support for tactical, resource allocation decisions.

HUMAN PERFORMANCE ANALYSIS AND ENGINEERING

BEST PAPER

Effects of Trust Calibration on Human-Machine Team Performance in Operational Environments

Beth Hartzler, Ph.D. • Sandro Scielzo, Ph.D. • Spencer Kohn, Ph.D. • Alvin Abraham • Rachel Wong

23210

Measuring mission-critical trust between human operators and collaborative synthetic teammates is a priority within the DoD to achieve third-offset goals, accelerate automation design and training for hybrid human-machine teams, and support next generation multi-domain warfare. Achieving proper trust calibration has long been a primary mechanism by which Human-Machine Team (HMT) performance can be maximized by avoiding system distrust and over-trust. However, proper trust calibration hinges on the implementation of effective trust calibration techniques based on real-time trust assessment. The current study establishes the relationship between HMT trust, workload, and performance in a Search and Rescue (SAR) paradigm where human operators supervise intelligent Unmanned Air Vehicle (UAV) assets to achieve mission success in a constructive synthetic environment. A novel trust measure was developed and piloted in this experiment to precisely measure subjective trust variations across time and in conjunction with target task elements. Thirty participants, including UAV operators and novices, participated in a rigorously controlled, within-subjects experiment that involved supervisory control of intelligent UAVs promoting collaborative decision-making via system recommendations across four SAR missions. Workload was manipulated by alternating the number of UAVs to supervise across each trial. Trust was assessed via our novel measure in addition to established metrics. HMT mission outcomes were measured via Measures of Performance (MOPs) and Measures of Effectiveness (MOEs). Objective biometric-based metrics were also used to measure operator workload using the Cognitive Workload Classifier (CWC), and Index of Cognitive Activity (ICA). Statistical analyses describe the relationship between trust, workload, and performance, and the impact of automated recommendation accuracy on HMT trust and mission outcomes. This experiment is unique as it provides a foundation for a real-time self-report measure of trust that can be directly compared to real-time physiological measures. Study findings further discuss intervention techniques to maintain proper trust calibration in operational environments.

Leadership Gaps in Army Training Organizations: Misunderstanding and Misapplication of the Instructional Systems Specialist (ISS)

Christina Parker, Ed.D. • Leonard Momeny

23144

This paper serves as the third in a series of studies for job performance and talent management of Army education professionals, specifically Instructional Systems Specialists (ISS), that has stretched from 2020 to 2022. The derived descriptive statistics from this paper provides objective insight into both TRADOC military and civilian Army Leader perceptions and expectations of job task and competency performance of the Instructional Systems Specialists (ISS). This information also supplements those previous studies within the series that were completed in from 2020 to 2021, in which perceptions and expectations from a sample frame of the Army's current ISS professionals were gathered regarding their own job performance Those previous studies identified a talent management gap in

that ISSs report performing Instructional Systems Design (ISD), otherwise known as ADDIE, specific tasks for which they must fulfill collegiate educational background requirements to be hired. The identified gaps also noted the ISS tended to act in more administrative and information management roles, rather than as the ISD specialist they were hired to be. A follow-on 2022 studied focused on job performance of instructors following their graduation from the current Army instructor training course. Given the COVID training environment, the 2022 study looked to whether instructor job performance was influenced by the modality by which the student-instructor received the course – resident or virtually. The 2022 study reported that measures of confidence in instructor ADDIE related job task performance was impacted because Instructional Systems Specialists were not consulted in the design and delivery of curriculum when transitioning from a resident to a virtual environment. This paper will confirm the noted gap from the previous studies but from the perspective of the Army Leader, thereby identifying, with great fidelity, the educational talent management issue current plaguing Army efforts to modernize education in support of Multidomain Operations.

Towards Robust Estimation of Cognitive Workload from Wearable Physiological Sensors

Aaron Novstrup • Monica Tynan • Gianluca De Luca • Joshua Kline • James Heaton

23235

Reliable, objective estimation of cognitive workload has potential applications in training (e.g., facilitating curriculum development), human performance assessment (e.g., treating workload itself as a performance metric), the design and development of human-automation teaming systems (e.g., evaluating the impact of design choices on operators' cognitive workload), and adaptive automation (i.e., adapting automation behavior based on the cognitive workload of human operators). A wide variety of physiological indicators of cognitive workload have been investigated over the past five decades, including heart rate/variability, respiratory measures, pupillometrics, electrodermal activity (EDA), and indicators extracted from complex sources such as functional near-infrared spectroscopy (fNIRS) and electroencephalography (EEG). However, individual physiological indicators are non-specific to workload and must be combined with others in order to derive a useful estimate. The sensitivity and specificity of joint estimates depend on the sensitivities of the individual indicators to variations in cognitive workload and the unique information contributed by each.

This paper explores the utility of face and neck surface electromyography (fnsEMG)—non-invasive, skin surface measurement of the motor action potentials that drive muscle activity—as a new sensing modality for cognitive workload and its associated emotional responses. The sensitivity of fnsEMG to cognitive workload variations at nine face and neck sensing locations was evaluated in a Defense Advanced Research Projects Agency (DARPA) funded human study in which participants performed multiple concurrent cognitive tasks in a modified version of the National Aeronautics and Space Administration (NASA) Multi-Attribute Task Battery (MATB). Task performance and frequent self-reports of task difficulty were compared with multiple physiological signals, including fnsEMG, electrocardiography (ECG), EDA, respiration, eye gaze, and pupil size. A machine learning algorithm was trained to generate well-calibrated predictions of task errors and self-reported task difficulty based on these physiological signals, demonstrating their combined sensitivity to cognitive load and overload.

Assessing Information Maneuver Performance and Effectiveness

Morgan Borders • William Ross • Michael Williams • Rebecca Goolsby

23268

Within the information environment (IE), adversaries exploit social media using their understanding of culture, beliefs, heuristics, and biases. Many challenges must be overcome to compete with these adversaries for global information advantage, including outwitting a highly adaptive, well-trained adversary; maintaining pace with advances in data science; the ubiquity of information technologies; and understanding relevant human performance capabilities. Further, effectively planned and implemented information operations produce measurable influence on decision making, perceptions, and human behaviors, but these effects can be difficult to measure. The current research began addressing these challenges by developing a method to examine and assess human sensemaking, problem solving, and decision making in the IE that provides the necessary data to inform decision making. Developing a well-rounded, technology-agnostic, and widely applicable assessment tool involved taking a systems perspective of information operations that combines the physical, informational, and cognitive aspects of the IE. Based on a previously developed mastery model of information maneuver analysts, we created a Behaviorally Anchored Rating Scale (BARS) consisting of 59 measures of performance associated with measures of effectiveness that can be used across the information domain. We further enhanced the BARS and facilitated reliable data collection by using the Field Assessment System (FAS), a complementary ONR project, to digitalize the BARS presentation and performance ratings. Leveraging Power BI for data visualization and performance analytics across several user-relevant dimension of performance made data synthesis user-friendly which affords easy interpretation to inform future research. This novel approach to information maneuver analyst performance assessment allows research across domains to focus on the cognitive performance beyond machine use in the IE, which offers application in any field. In this paper, we illustrate the foundation and development of the OMEN measurement and assessment system from the perspective of the human performance and not the enabling technologies.

The Criticality of Human Computer Interface/ Human-Machine Interaction for Healthcare

Steven Michael Thomas • William Marx, Ph.D. • CAPT Timothy Hill, USN (Ret.) • Chanler Cantor

23277

As advanced technology continues to permeate the DoD and healthcare simulation enterprises, Virtual Reality (VR) systems coupling Head Mounted Display (HMD) systems with advanced

commercial rendering, have transitioned from entertainment applications to powerful tools for serious applications in modeling, simulation, and training. Caution is warranted prior to adoption of the technology, as Human-Computer Interaction (HCI) and the Human-Machine Interface (HMI) are arguably more critical in the design and development of these systems given the users' full immersion in these digital environments. Inadequate testing and validation can potentially lead to negative training more readily, and so care must be taken to ensure accurate representation of both the environment and the user interaction with it. The software and hardware systems need to be developed and tested using best practice methods for HMI and HCI.

The paper will discuss our research and application of HMI/HCI to ensure that VR systems intended to be used as Software as a Medical Device (SAMD) are sufficient for the intended use. Despite the growing use of 3D displays and visualization, current standards for healthcare displays are based on traditional 2D monitors. We will discuss our methods of ensuring compliance with the ACR–AAPM–SIIM Technical Standard for Electronic Practice of Medical Imaging (PMC3553359) for a VR system. The paper will also describe HMD hardware testing to characterize luminance and distortion to ensure that system preserves and presents accurate and clear 3D representations. A survey of technical literature in this area will be presented, while also including how our methodology contributes to advancing the practice.

We conducted clinical validation of our SAMD in a simulated clinical environment and hardware characterization testing to quantify and measure HMD performance. This integrated set of results was used to ensure that our SAMD system provided a clinically useable system that accurately represents the physical world, in terms of both software and hardware presentation.

Team Training for Collaborative Cross-Functional Problem-Solving in Wargaming Exercises

Randy Jensen • Grace Teo • Lisa Townsend

23325

Course of action (COA) development and wargaming are critical stages in the U.S. Army's military decision-making process (MDMP), where command staff at battalion and higher echelons analyze COAs in detail, considering actions, enemy reactions, and counteractions. Teamwork behaviors involving coordination across warfighting functional areas are essential to wargaming effectiveness and therefore central learning objectives in training. Full-scale wargaming exercises involve teams-of-teams, as different functional leads and their subordinate staff make decisions and projections relevant to major COA events, to produce a detailed, synchronized operational matrix. In order for a training audience to work effectively in full-scale wargaming, there is a need for preparatory collaborative exercises where they can gain greater awareness as to their specific roles and contributions, and those of other team members. This paper describes a distributed training tool developed to prepare staffs for full-scale wargaming with a browser-based synchronous team dimensional familiarization exercise guided by an instructor. The exercise is presented as an integrated wargaming vignette, where command staff participants are prompted to review COA events and consider the role and impact of different warfighting functional areas. Since the exercise focuses on teamwork, much of the emphasis is on participants identifying relevant questions to be considered in the decision process, without the additional overhead of determining scenario-specific answers. Team performance assessment is captured via teamwork markers associated with an assessment model organized around team dimensions tailored for wargaming. Markers are created both by instructors and automated system rules during the exercise, for later incorporation into a debriefing for team self-correction. Markers are tagged with salient team constructs, qualitative assessments, and annotations about the flow of knowledge across warfighting functions. This paper presents initial training tool feedback from experienced instructors, as well as further discussion of the tradeoffs in team training for wargaming and other collaborative problem-solving domains.

Dangers and Solutions for Systematic Misinformation at Scale

Joseph Regian • David Noever

23332

Instantaneous sharing of information (fallacious or not) to large and sometimes uniquely receptive populations is routine. Cognizant entities (individuals, groups, religions, governments, software agents, bots, etc.) can now selectively find information affirming what they already believe to be true by attending to information resources consistent with their existing preconceptions and ignoring or even filtering out information that is inconsistent. No specific entity class (e.g., Democratic vs. Republican) is more susceptible to misinformation vulnerabilities than another. Human individuals are particularly susceptible. Misinformation vulnerabilities are known to occur even unconsciously. This is well known to the intelligence community as confirmation bias (selective search, interpretation, recall). In any analysis or search, the easiest thing to find is what you are looking for. qually important, hostile entities or propagandists can selectively push information to other entities to influence the world views, opinions, and behaviors of the targeted entities. We argue that these dangers are potentially more severe in the cases of government officials, law enforcement, intelligence agencies, and military personnel – who daily make decisions effecting the safety, security, and the very lives of the general population. There is no reason to believe that misinformation proliferation and acceptance is any less prevalent among military personnel than it is among the population in general. This research seeks to characterize the technical characteristics that lead to proliferation of misinformation and explores 2 classes of technical solutions to address the dangers of unchecked misinformation proliferation and adoption. The first class we refer to as Information Flow Modeling (IFM), developing capabilities to model and visualize information pedigrees. Where did this information originate, what entities are pushing it, what entities believe it, what is the agenda of the source entities? The second class of technical solutions are job support and training systems for Critical Thinking (CT). We describe and demonstrate both classess of technical solutions.

Unobtrusive Measures and Understanding Team Processes

Alexxa Bessey, Ph.D. • Kara Orvis, Ph.D. • Robert McCormack, Ph.D. • Marissa Shuffler, Ph.D. • Tara Brown, Ph.D. • Dorothy Carter, Ph.D. • Amanda Thayer, Ph.D. • Eduardo Salas, Ph.D.

23337

The need to examine team processes with more innovative approaches is well-documented, as much of the literature has utilized self-report or subjective measures which are often biased, intrusive, and/or provide a static, retrospective evaluation (Kozlowski & Chao, 2018). Further, in the military, it is often impossible or unrealistic to have trained observers in dangerous or classified environments, or for warfighters to stop their tasks to take a survey. Recent advancements in technology (e.g., wearable sensors), coupled with the issues related to subjective data, have created new opportunities for researchers to examine team processes using less invasive or obtrusive approaches (Orvis et al., 2013). While such advancements in technology are promising for the development of unobtrusive and objectives measures, there are also well-documented concerns regarding the lack of rigor in the development of unobtrusive measures as they often lack conceptual or theoretical backing (Salas et al., 2015). As a result, the following paper takes a comparative look at an unobtrusive measure developed using a rigorous framework, the Rational Approach to Developing Systems-based Measures (RADSM; Orvis et al., 2013), with subjective measures from observers and survey assessments. The following paper utilizes data from a large-scale, military-inspired experimental research study with a variety of unobtrusive data (i.e., audio data, video data, and positional data) and subjective data (i.e., observations, survey measures) collected from five-person teams completing a military-like exercise. We present best practices for measure development and validation as well as insights regarding the strengths and limitations of both unobtrusive and subjective measures so that readers can better understand the different methodologies of capturing team processes and the implications of both within their own work. Lastly, we discuss the utility of quality unobtrusive data for optimizing team performance and assisting leadership in making personnel and team composition decisions.

Learning Engineering Virtual Training Systems with Learning Science, Data Standards and a Capabilities Maturity Modeln

Kevin Owens • Shelly Blake-Plock • Jim Goodell

23399

Recent engineering requirements for simulation-based training devices and content are focused mainly on a device's material design, and the software-based rendering engines, terrains and entities needed for these devices to function. What has been left out of simulation-based training device requirements are the conditions, attributes, data and standards of human learning a device must produce, suggesting learning should be the device's primary quality indicator. Missing requirements include an ability for trainers or learners to design measurable synthetic experiences for specific learning outcomes, based on the latest learning-science, and the levels of learning evaluation a device must achieve. This includes measuring against data from comparable live-training experiences. Another requirement missing in modern simulation-based devices is the ability to extract the human learner's cognitive and psychomotor data required to independently verify learning requirements are objectively met. To create and properly manage these types of requirements, the process of learning engineering must be integrated into the modeling and simulation engineering program.

Learning engineering (LE) is the practice of finding science-based, user-centered, and data-informed solutions for human learning needs, problems or challenges. Very similar to traditional systems engineering, learning engineering provides a system-of-systems approach, and the superposition perspective required to design across the multiple phases of simulation-based training but with the primary objective of improving human learning outcomes. This includes managing the multiple additional occupations and disciplines required to develop and evaluate simulation devices, and the types of content design and data outputs required to ensure the device's learning production, and the learner's return-on-investment is maximized.

This paper will discuss a use-case of the learning engineering process integrated into the design, development and evaluation requirements of simulation-based training device hardware, software, experience design, and learning assessment methods required to achieve a standard of human learning, based on learning-science and inspectable and reproducible data outcomes.

Taking Control: An HFACS Analysis of Loss of Control in Helicopter EMS Flights

Paige Lawton • Albert Boquet

23403

INTRODUCTION: Loss of control (LOC) accounts for approximately 40% of fatal accidents in general aviation and roughly half of all aviation fatalities. Within Helicopter Emergency Medical Services (HEMS), LOC is an increasingly pressing issue contributing to fatal accidents despite new rulings by the FAA in 2014 intended to improve safety in HEMS operations. This analysis aims to explore the causal factors which contribute to LOC within HEMS.

METHODS: Helicopter Emergency Medical Service accidents occurring between the years 2014-2019 were pulled from the National Transportation Safety Board (NTSB) accident database. Inclusion of FAR Part 91 and Part 135 accident flights resulted in a total of 26 accidents. Causal factors contributing to each accident were then coded using the Human Factors Analysis and Classification System (HFACS). Analyses to obtain frequencies were completed using IBM SPSS.

RESULTS: Of the 26 accidents that occurred between 2014-2019, a total of 17, or 65.4% were associated with LOC. Of these LOC accidents, 54.5% were preceded by inadvertent flight into IMC and were associated with skill based errors (47%). Finally, over half of these accidents (58.8%) resulted in at least one fatality of those on board.

DISCUSSION: Despite new rulings implemented by the FAA, HEMS operations continue to struggle with managing the risk associated with providing emergency and other medical transport

for patients. Like other aviation platforms, LOC is a persistent threat to both crew and patients. Preliminary results of an HFACS analysis indicate that skill based errors are the largest contributors to these accidents, prompting further examination of the factors contributing to these errors. It is also worth noting that of the accidents where LOC occurred, over 50% of these involved at least one fatality. Further analysis should focus on the role of current training practices and operational guidelines within HEMS to determine potential strategies for mitigating risks associated with loss of control.

Pilot Performance Assessment Using a Hybrid Expert System and Machine Learning for An Automatic Objective Assessment in Flight Simulation

Jean-Francois Delisle • Andrea Lodi • Maher Chaouachi • Melvyn Tan • Laurent Desmet

23411

An automatic pilot assessment capability using machine learning algorithms that can inform a flight instructor during a flight training session in full flight simulators is proposed in this paper. The current research explores a hybrid expert system and machine learning capability to assess pilot performance in flight simulation. Hybrid rule-based and machine learning algorithms are considered in the approach. Assessing a pilot's performance during a flight training session is a capability that can considerably improve the effectiveness of a training session and help the flight instructor provide better instructions and feedback. In this paper, we investigate an efficient way to build an automatic objective assessment engine, that provides a performance index that uses both knowledge of subject matter experts and instructors to train the artificial intelligence capability. By using multi-labels that have the same meaning but come from different sources of knowledge, we demonstrate that an automatic assessment engine is able to reduce the subjectivity of the instructor and optimize the time of the rules creation, tuning, and testing effort for the expert system development. In addition, we show that this hybrid approach increases the accuracy and precision of the assessment of pilot maneuvers during training sessions by using a consensus methodology that blends the multiple sources of knowledge.

A Framework for Performance Assessment Across Multiple Training Scenarios Using Hierarchical Bayesian Competency Models

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

23431

This paper combines cognitive task analysis and expert input to design and develop a framework for assessing learner competencies and performance across multiple training scenarios. We adopt a hierarchical Bayesian approach to aggregate information from multiple modalities to derive competency metrics that relate to team coordination and individual psychomotor, cognitive, and affective measures of performance. The unified framework is represented as a task model that maps onto multiple task domains. The resulting hierarchical competency structure connects observed low-level performance measures for each task domain into higher-level competencies that are common across domains. By utilizing Bayesian inference to propagate evidence up the competency model, our framework is able to build a common model of high-level learner cognitive and psychomotor performance using evidence from multiple independent tasks. We demonstrate the effectiveness of the proposed framework using a case study of groups of soldiers performing two dismounted battle drills, and show that the performance displayed by the soldiers provides consistent evidence for their higher-level competency states. With continued research and development, the proposed framework could allow for consistent longitudinal assessment of trainees based on observable evidence across a wide variety of domain skills and tasks.

Me and My Report: A Segmentized After-Action Review Embedded Report Application for Supporting Maintenance Training in VR

Nir Keren, Ph.D. • Andrew Lawson • Robert Johnson • Amon McAllister • Angela Leek • Ashwin Jacob • Aiden Webster • Christopher Boswell • Glenne Goode

23449

After-action review (AAR) has been used extensively for debriefing in post-operation or post-training sessions. The military heavily relies on AARs for reviews.

Training for performing proper inspection and maintenance procedures is of utmost importance. The various inspection and maintenance procedures often include a large number of elements that are quite complex. The Air Force, Navy, and Army could only conduct their operations successfully if they could rely on their maintenance teams. Yet, a literature review failed to identify works about utilizing AAR for maintenance functions. The authors developed an immersive VR simulation framework titled MVE-VR for conducting Level VI inspections of radiological shipments, where Motor Vehicle Law Enforcement officers can get trained to inspect vehicles transporting radioactive material. A proper Level VI inspection could last 45-90 minutes and include a few hundred inspections. The extensive efforts associated with these inspection procedures make capturing and reviewing inspection violations difficult. The MVE-VR framework consists of a simulation application and a separate report application that captures 1) all inspection items during the training and 2) the simulation experience in the VR. The report application is designed to segmentize the VR simulation experience (the Post-simulation AAR) to deliver replays of the experiences at the relevant simulation point on a desktop. The research team hypothesizes that MVE-VR facilitates an enhanced interactive learning engagement that will yield superior results compared to a simple post-inspection report that does not include the Post-simulation AAR and the non-simulated report applications used currently. Experiments will begin soon. Why is this of interest to the community? While significant efforts are devoted to developing extended reality applications for maintenance, the merit of a segmentized AAR application for inspections and maintenance has yet to be

examined. The proposed framework has the potential to create a dent in developing teams that are well-trained to handle complex maintenance operations.

POLICY, STANDARDS, MANAGEMENT AND ACQUISITION

BEST PAPER

Developing the Human Machine Teaming (HMT) Ecosystem

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23233

Department of Defense (DoD) investment in artificial intelligence (AI) and machine learning (ML) related efforts has amounted to hundreds of billions of dollars over the past five years. Driving this high level of investment is AI/ML's potential to unlock revolutionary new capabilities for the warfighter. Use cases explored by the DoD include Project Maven's imagery analysis, CADO's SmartSensor, and DARPA's Air Combat Evolution (ACE). While these programs have shown AI/ML's utility and promise, they have only been deployed in isolated or developmental environments. Moving forward, to truly realize the potential of operationalized AI/ML technology, more complex and real-world representative use cases are required.

One such use case within the DoD is Collaborative Combat Aircraft (CCA). The goal of CCA's is to develop and deploy autonomous combat aircraft to augment and enhance today's resource constrained fighter pilots. While the DoD has successfully deployed AI/ML on a more limited scale, the CCA effort represents a large increase in mission and system complexity. The program will require seamless integration of unmanned aircraft, manned aircraft, advanced sensing methods, high performance edge computing, manned-unmanned teaming (MUM-T), AI/ML aircraft control algorithms, simulation-based training for operators and rapid AI/ML algorithm retraining for securely updating autonomy at the speed of relevance. As a result, the CCA ecosystem will require government, manned aircraft providers, unmanned aircraft providers, and autonomy software developers to work together in an agile and open way. The work in this paper aims to begin the CCA ecosystem development process by decomposing and describing critical components. After defining and describing these elements, the authors then begin exploring policies, standards, and management practices required to ensure effective CCA deployment. Ultimately, the work presented in this paper helps begin defining the CCA ecosystem's components and their interfaces to ensure delivery of powerful new warfighter capabilities.

A Hybrid Approach to Combat Simulation Experimentation

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23106

In order to ensure the validity of a warfighting experiment, the experimenter must be able to detect change, isolate its cause, and relate experimentation results to real-world (combat) operations. Constructive simulation experiments (SIMEXps) with multiple runs are ideal to detect change and to isolate its cause. However, because modeling complex events requires many assumptions, critics often question the applicability of constructive simulation results to operational situations. This is juxtaposed by command-and-control human in the loop (HITL) experiments in which military staffs receive real-time, simulated sensor inputs, make real-time decisions and direct simulated friendly forces against simulated threat forces. The use of actual military operators and staffs allows this type of experiment to reflect warfighting decision-making better than purely closed-loop constructive experiments thus increasing the applicability to real world operations. However, when humans make decisions, variability increases, and changes are more difficult to detect. The Maneuver Battle Lab (MBL) uses a hybrid approach to SIMEXps to capitalize on the strengths of both the closed loop constructive and HITL approaches, while minimizing the weaknesses of each technique. The MBL uses operational force military role players (MRPs) to replicate staffs during HITL SIMEXps to ensure applicability to real-world operations. The tactics developed by these MRPs – during several replications per case – are then scripted into the simulation scenario and replicated in a constructive (or closed loop) manner for the required number of times to ensure statistical significance. The hybrid approach described in this paper provides a means for other organizations conducting military experimentation to increase the validity of their constructive experiments, while simultaneously increasing the real-world applicability of their experiments. Ultimately, this paper will provide a means to increase both qualitative and qualitative analysis to help substantiate outcomes. The paper will include previously conducted use cases, potential uses of the hybrid approach, and areas for continued development.

Remodeling Readiness: Using Digitization to Enable Organizational Expertise

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23129

Ensuring force-wide training and readiness requires comprehensive data describing job requirements, training histories, and proficiencies. Although the U.S. military has created numerous systems that seek to collect and maintain human performance data, a significant gap remains in the lack of shared digital expressions of readiness across the ecosystem. In this paper we discuss and illustrate the benefits of implementing centralized competency framework definitions that can be leveraged for actionable insights across the full training and readiness lifecycle. Our approach, developed and demonstrated over numerous recent Navy, Army, and Air Force projects, supports a transition to competency-based analysis and tracking through a process we term “digitization”. We describe how our semi-automated

digitization techniques capture all available data that defines what personnel should know and do within a military organization. Such data can include: (1) who a person is and their training background; (2) the job duties associated with a person's role and assignments; (3) what a person has demonstrated they know and can do; (4) what credentials a person has earned; and (5) what a person's capabilities and goals are according to their organization. We discuss active military use cases to illustrate how digitization involves transforming legacy artifacts that describe human experience, capability, potential, expectations, and insights into machine actionable URI-referenceable data, typically Linked Data. Linked Data can be threaded between URL identified data (skills, competencies, etc.) and training systems. Expressing occupations and related information as Linked Data allows systems to perform rapid analysis by uniformly following data trails across system, organizational, and authoritative boundaries.

We conclude with a discussion of how our digitization approach generalizes to provide organizations a foundation focused on the human element of training and readiness, enabling a data-driven accelerator for sustaining a global force in a digital world.

Development of a Digital Simulation Supporting the U.S. Space Force National Test and Training Complex

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23133

The United States Space Force (USSF) was signed into law as part of the 2020 National Defense Authorization Act in recognition that our competitors and adversaries have turned space into a warfighting domain. Potential adversaries recognize the advantage the US gains by operating in space. They are responding, fielding their own systems to exploit the domain and holding US space systems at risk to deny our use of space. The Defense Space Strategy identifies a phased approach to encourage innovative and bold actions to ensure space superiority. Given the challenging and costly nature of testing in space, simulation may be the best option available that allows for the USSF to characterize the complex, system-of-systems (SoS) environment, while mitigating the costs and protecting sensitive mission capabilities that may be revealed by on-orbit testing. The USSF is developing a National Test and Training Complex (NSTTC) to provide critical infrastructure to enable operationally relevant test and training of all-domain, SoS capabilities that form the enterprise response to increasingly sophisticated adversary capabilities and tactics. This paper will concentrate on the development of the digital simulation environment (aka NSTTC-D). Specifically, the authors will discuss how the development team is successfully leveraging test and training Mission Engineering and Model Based Systems Engineering to inform a scaled agile development process based heavily on software and model reuse. As such, the NSTTC-D team will engage heavily in collaboration with the modeling and simulation community from a multi-service, industry, and academia perspective. The reader should be provided with an understanding and appreciation for the NSTTC-D test and training initiatives, tailored simulation processes/challenges, and path forward leveraging simulation as part of its vision to provide space warfighters with a digital venue to develop, validate, and sharpen joint warfighting solutions.

An Ontology-based Approach for Scenario Generation in Flight Simulation Systems

Hung Tran • Michael Tillett • Howard Cheung

23135

The core component of a simulation-based training system is the process of creating training scenarios. The scenario creation process is essential for simulation-based training systems since scenarios are designed to provide the context for the training to occur. An effective training scenario should provide opportunities for trainees to practice their skills, and receive feedback from the instructors on their performance. A training scenario is normally characterized by three main components: (1) the initialization, (2) the key events that must happen during the training, and (3) the termination conditions. Prior to developing a training scenario, training objectives must be analyzed to determine the set of knowledge and skills that are required as part of the training to ensure that scenario outputs are domain-valid and pedagogically effective. Because of this reason, the creation of validated and effective training scenarios must be carried out by qualified instructors and highly trained subject matter experts. The process is challenging and time-consuming, therefore expensive. The objective of this paper is to describe an approach that will facilitate the task of the generation of training scenarios. The proposed method is based on the ontology of knowledge presentation. The paper presents an ontology developed to capture simulation scenario attributes that are pertinent to the flight simulation domain, and describes the role of this ontological analysis in the process of creating training scenarios. Leveraging the SISO interoperability standard, this study expands the C2SIM core ontology by adding a Training Scenario Extension layer to it. As a result, training scenarios can be generated in a standardized format that complies with the base and extended C2SIM ontology. Finally, the paper will present a use case of air refueling training as an application of this approach. This work constitutes an important step towards standardizing practices in automated simulation scenario development for flight simulation applications.

Standard Protocol Stack Improves Short-Range Wireless Communication in Live Simulation

Thierry Hischier • Reto Haldemann

23195

Personal Area Networks in Live Ground Force Simulation are used for communication between simulated weapons and sensors, user interfaces or as radio interface for tactical engagement systems. They require high reliability, short/middle range transmission and low power consumption for battery supplied systems. In the past, the implementation of such systems were often based on a combination of standardized protocols and proprietary solutions. This has the consequence that the functionality between different systems and providers cannot be guaranteed, so that

the connection of third-party systems was not possible, whereas interoperability of such systems would allow training between different forces from different countries.

This paper will explore and conclude that the use of a complete single industrial standard protocol for short-range wireless communications allows access to existing mature implementations and solutions, speeds up development processes and reduces development costs, as well as providing interoperability between different parties as all simulation equipment can be perfectly adapted to the respective needs.

Bluetooth Mesh allows to connect or exchange data between different simulation systems. The companies behind this large wireless technology promise perfect support and implementation for all extensions of the existing specifications.

A single-chip solution can reduce recurring costs, increase reliability and reduce the power consumption. This includes not only less expenses for procurement, but also lower expenses for maintenance and servicing.

The integration of an international radio standard opens a variety of new possibilities, such as the ability to communicate with many 3rd party COTS products such as smartphones or other devices.

The introduction of Bluetooth Mesh, a universally applicable radio standard based on Bluetooth Low Energy, provides an elegant solution for various components and systems. This standard offers added value for all parties involved in the Live Simulation space, making it a valuable tool for enhancing interoperability and functionality across different systems.

A Data Strategy for Data-Driven Training Management: Artificial Intelligence and the Army's Synthetic Training Environment

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23262

The U.S. Army's Synthetic Training Environment (STE) and supporting training and learning concepts define Artificial Intelligence (AI) as a functional requirement to optimize the use of simulation to support individual and team readiness requirements. A current limitation to technologic tools examining AI is access and proper management of meaningful data. Many AI methods are developed under controlled and isolated settings with limited use cases and data-points. These investments prove a methodology from a technology readiness standpoint, but often fail to meet the intent of having ready-to-transition AI services that create valid measures and drive calculated decisions. In this paper, we will present a strategy for defining data requirements and management to support an evolutionary approach to AI development and validation.

How do we directly address this issue? Establishing a data strategy on standards, best practices, acquisition requirements, and mission threds can produce data repositories (i.e., buckets) specifically implemented to drive AI maturation. This emphasizes collecting data with a purpose, and establishing explicit implementation guidelines that align to desired end-state AI capability. This position is explored at a high-level in the context of STE and future Programs of Record. We will present a framework based on AI services associated with adaptive training management, the type of functions each service provides, and the type of data bucket required to drive its utility. Services explored include building more objective assessments across multi-modal data and across training iterations; building personalized feedback and scenario adaptations that target strengths and weaknesses; creating recommender engines for guided training progression to maintain proficiency; and building realistic synthetic entities that enhance training fidelity. Each of these services demand careful consideration for data instrumentation and management. Beyond persistent storage, we will present recommendations for the capture, contextualization (i.e., metadata/labeling) and retention of data to drive evolutionary maturation of each AI function.

Enabling Distributed Maritime Operations Through Live, Virtual, Constructive Technologies

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23272

Distributed Maritime Operations (DMO) is a Naval operating concept intent on reclaiming and expanding United States' naval effectiveness where land, air, sea and information superiority are challenged, logistics are contested, and forces are distributed over large distances. Key to DMO is the ability to plan and execute synchronized operations across multiple, geographically distributed warfighting domains using a diverse range of forces. Realizing this vision requires technologies to test operational plans and teach, in real time, key concepts in an integrated, synchronized and cross-platform manner. Live, Virtual, Constructive (LVC) technologies, which link high-fidelity simulations, real-world activity and, constructive teammates and adversaries using integrated networks, provide one approach to realizing the large-scale and distributed actions DMO requires to succeed. Despite many recent advances, LVC applications are still in their infancy, with a proliferation of "one off" capabilities that solve a small specific gap but lack application to broader LVC initiatives. These challenges are further exacerbated by the lack of a consolidated Navy roadmap that supports overall training and readiness necessary to operationalize DMO as a warfighting concept. Thus, a need exists to develop a unified LVC implementation framework to focus investments, increase transition, and provide speed to the fleet over the next 30 years. This paper provides an overview of an LVC implementation framework developed in coordination with key Naval stakeholders and LVC leaders from other Services and Coalition partners. The framework enables alignment of emerging stakeholder needs contextualized in DMO with current/desired LVC capabilities. Importantly, the framework also provides a way to inform new capability research investments and identify existing solutions to leverage. While long-term value of this framework requires continued monitoring/assessment, this is a first step in delivering an integrated and unified approach that enables DMO to deliver situationally aware forces that are prepared to outthink, outperform and overwhelm adversaries.

Virtual Pathways: Application of the Adaptive Acquisition Framework for Synthetic Training Environments

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23288

Never before in DoD acquisitions have Program Managers been provided the speed and flexibility to expedite innovation than that afforded by the recently implemented Adaptive Acquisition Framework (AAF). This groundbreaking policy restructures defense acquisition guidance to improve process effectiveness to increase the speed of innovation for critical defense technologies and services. Coupled with other powerful acquisition tools such as Other Transaction Authorities (OTAs), the AAF provides PMs with multiple pathways for tailoring successful prototyping and delivery of critical technologies directly to the Warfighter and stakeholders. The introduction of the AAF has proved opportune for the U.S. Army who have fully embraced this policy through the emergence of the Synthetic Training Environment (STE) family of programs. This has enabled the U.S. Army to be the premier adopter of two principal pathways associated with the AAF – Middle Tier Acquisition (MTA) and the Software Acquisition Pathway. Through these unique acquisition methodologies, the U.S. Army has been able to accelerate capabilities to the field through a series of informative Soldier Touch Points and Operational Assessments. As an early adopter of these pathways, the U.S. Army is setting a standard for successful implementation on these policies. This paper seeks to expand upon the progress to date by the U.S. Army STE programs on the implementation of these two AAF pathways, as well as provide valuable lessons learned and recommendations for those programs and DoD agencies looking to apply these powerful acquisition tools to emerging defense programs.

The Digital Twin Encapsulation Standard: An Open Standard Proposal for Simulation-Ready Digital Twins

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23352

As modular, digital twin based simulation moves towards broader adoption, the need for interoperability becomes increasingly evident. To invest in a significant digital transformation, enterprises need assurance that their digital infrastructure will be meaningful and long lasting. There is a growing urgency for a stable, open-source framework and standard that can assure customers that their digital twins will be flexible enough to function in any context relevant to the physical twin, and will not be locked into any single platform or workflow as their needs and use cases evolve.

While significant work has been done to delineate the requirements for a unified framework, a viable and agreed upon proposal has yet to gain traction. Currently available standards, while useful, tend to be highly domain specific, and therefore fall short of introducing true interoperability.

Resulting from several years of iterative work with our customers we arrived at a conclusion: a standard that prescribes how a digital twin will be used limits interoperability and adoption. Instead, we evolved a standard that can encapsulate all the data necessary for the utilization of a digital twin and can always be extended for specific domain utilization. Our Universal Scene Description-based (USD) standard is information rich and highly extensible, and we have labeled it the Digital Twin Encapsulation Standard (DTES).

The aim of this paper is to introduce this standard in detail and explore how it has evolved through customer engagements and insights. It illustrates how an encapsulation approach can make digital twins simulation-ready regardless of the chosen execution environment. We expand on the levels of data organization and their associated properties and invite the simulation community to review, challenge, adopt, test, and evolve this proposed standard through a collaborative process.

Cyber Resiliency at the Edge – From Technology to Policy

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23353

Information technology has grown rapidly in complexity, capability, and affordability, making IT one of the largest data generators within an organization. This data must be parsed, related, consolidated, and evaluated to provide continuous monitoring and allow for the identification of potential threats; as the amount of data increases so do cost and labor to perform these activities. This data is often initially designed to only inform but increasingly, via the growing adoption of artificial intelligence, to take action. While the connected enterprise can leverage numerous tools that promote cyber resiliency, the closed, restricted networks of aerospace industry labs and platforms that must operate in remote environments (aka the “edge”) are constrained either technically or financially. The networks, disconnected from the Internet and the global information grid, are essential to the operation of our critical infrastructure and national defense, but their disconnected nature does not remove the need for continuous monitoring and cyber resiliency. This can lead to a false sense of security from both insider and external threats when the risk is falsely perceived as relatively low. The need for continuous monitoring and cyber resiliency has led to the decrease in waivers in defense. Critical infrastructure (CI [i.e., energy grid, supply chain, etc.]) is an active target for adversaries and threats within the homeland. Cyber resiliency and continuous monitoring at the “edge” are essential to ensure that our services and capabilities are available where and when we need them. The authors are applying their experience in tools, compliance, and threat hunting to enterprise-level CI and defense networks. Our paper will present a literature survey of methods and limitations for deploying cyber resiliency to the edge. It will describe our methods and contributions to provide edgeresiliency - for continuous monitoring and remediation of vulnerabilities to threats, both internal and external.

Augmented Maintenance: Setting Expectations for Augmented Reality

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23360

Augmented Reality to support maintenance has been an area of study for over 50 years. In recent years, advances in commercially available hardware platforms offer increased potential value from augmented reality solutions. Like an aircraft heads-up display, Augmented Reality systems insert information in the maintainer's visual field and, using a camera, can interpret and analysis what the user sees, potentially sharing that information with a remote collaborator. The enhancements provided by Augmented Reality on a maintainer's workflow can range from intuitive access to digital documentation that can increase time on task to real-time computer-assisted visual assessments that reduce both maintainer cognitive load and likelihood of errors. However, Augmented Reality platforms can vary drastically in terms of capabilities and the effects they can have on the human visuomotor system. For example, without appropriate matching to the distance of the work, stereoscopic Augmented Reality headsets with lead to eye strain and impair a maintainer's ability to assess distance. Differences in onboard cameras can degrade an Augmented Reality platform's ability to present relevant details in the visual field and lead to misleading assessments of task performance. Obtaining optimal value and benefits from investments in this technology requires consideration of the unique characteristics of each combination of platform, use environment, use case, and the content that will be presented. Our paper will present guidelines to consider when purchasing Augmented Reality solutions to help potential users determine appropriate maintenance-based use-cases and estimate the return on investment from purchases of augmented reality technology. In the paper, which is follow-on work to a paper presented at I/ITSEC 2022, we will explore the types of platforms used to drive visual augmented reality, how these platforms integrate with the human visuomotor system, how hardware limitations limit the capabilities of a platform, and rules of thumb to define platform requirements based on the use case.

AI/ML-Driven Content Repository Maintenance

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23365

Accurate and relevant knowledge repositories are critical to all organizations and are especially vital to the United States Navy; Sailors' knowledge gaps or inaccurate content could lose billions of dollars and risk human life. Continuous updates to knowledge repositories are a well-documented strategy to avoid the obsolescence of knowledge management systems (Malhotra et al, 2010). In this work, we introduce our instructional content repository, a "YouTube for the Navy" that makes crucial content easily accessible and allows repository maintenance to keep content accurate and up-to-date.

Repository maintenance can be laborious and prone to human error. To increase the accuracy of repository maintenance processes and reduce the need for human labor, our team is applying AI/ML-driven methods to automate and scale repository maintenance for the United States Navy. Leveraging Google Cloud Platform's Vertex AI video intelligence tools and custom algorithms developed by our Carnegie Mellon University partners, we outline several repository maintenance methods that will be tested with a Navy squadron during our Phase II STTR, including Tech Pub Alignment, Comment-Derived Flags, Moment Detection, and Video Segmentation.

An Inflection Point for Defense Modeling and Simulation (M&S) Management – Redefining Roles and Responsibilities Across the Department's M&S Enterprise

Scott Schutzmeister • Annie Patenaude

23410

The evolution of Defense M&S Management spans over thirty years starting with the establishment of the Defense Modeling and Simulation Office (DMSO) to serve as the DoD focal point to promote effective and efficient use of modeling and simulation. While historically having broad responsibilities covering multiple "communities enabled by M&S" plus international technical collaboration, the more recent DoD issuance have narrowed that scope to support acquisition-centric activities. This evolution is made more complex by the emphasis in the Department on model-based systems engineering, and digital engineering. Thus, there is a need to reexamine governing and collaborative best practices to allow stakeholders and decision makers to redefine roles and responsibilities to best manage and modernize M&S capabilities.

This paper provides insights on the evolution of Defense M&S Management and assesses the more recent capabilities and methodologies of both M&S functional communities and Service-specific management offices. The discussion details the key phases of Defense M&S Management, from an emerging technology (1991-2005), to a focus on transformation (2006-2014), to high level coordination and engagement (2015 and beyond). This is followed by a scoping methodology to investigate areas of need from the current M&S organizations to the desired outcomes from key stakeholders of M&S capabilities. Discussion topics include governance and collaboration best practices, and comparison of roles and responsibilities across the department, to include the applicable issuances and resourcing.

Finally, the paper assesses cross-community and service-centric challenges in M&S modernization from planning to implementation and evaluation. This includes examination of existing management functions and recommendations on strategy development, policy formulation and workforce development as it affects the Defense M&S enterprise.

The NISP Standard (NATO Interoperability Standards and Profiles) and Data Governance

Colonel Alexandre Freitas

23454

With increased cooperation between allied countries and the increasing complexity of military operations, interoperability

between military information systems has become a critical need. Without the ability to effectively and reliably share information, military forces risk operating in an uncoordinated and inefficient manner, compromising the security and success of operations. In this context, NATO developed the common data interoperability standard (NATO Interoperability Standards and Profiles - NISP), which establishes technical requirements for the exchange of information between military information systems of different NATO countries. NISP defines standards for data structure, format, and content, as well as for communication interfaces and protocols. NISP is divided into interoperability profiles, which are sets of specific technical requirements for different types of military information systems. Each profile defines requirements for exchanging information in a specific operational context, such as data interoperability for maritime operations or data interoperability for air defense operations. The NISP is an essential component of NATO's data governance framework as it ensures that information shared between allied countries is accurate, reliable and secure. In addition, NISP promotes interoperability between military information systems, allowing allied forces to work together effectively and in a coordinated manner in joint operations. Implementing the NISP is a complex and challenging task, as it involves the coordination of various military and government organizations from different NATO countries. In addition, the constant evolution of information and communication technologies requires that the NISP be regularly updated to adapt to new demands and requirements. NISP is an essential part of NATO's data governance, which promotes interoperability, effectiveness and coordination of joint military operations.

SIMULATION

BEST PAPER

Developing Criteria to Compare Military Medical Trauma Simulations Across Modalities

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23241

The military trains medics on trauma management procedures using various methods and modalities of simulation. Simulation modalities for medical training may include manikins, part-task trainers, augmented/virtual reality, computer-based simulations, cadavers, or live tissue training. Each modality has benefits and limitations for training, such as suitability for training a certain task, cost, scalability, and deployability. To determine which simulation modality should be utilized and in what context, it is important to establish what features are needed to train specific medical tasks and to understand the capability gaps of each modality.

To establish whether a simulation meets the needs of military medical training and assessment, evaluation criteria were developed for twelve trauma procedures based on existing military doctrine for certifying competence of medics in tactical combat environments. For each procedure, a checklist was developed that consisted of a series of steps needed to complete the procedure successfully and the necessary simulation features corresponding with each step. The checklists can be used to compare different simulations on the same scale across modalities. A pilot study was then conducted as part of a military Technical Experimentation (TE) event. Military medics were asked to complete the checklists of features for each medical simulation. Following the checklist, evaluators were asked to rate modalities on factors of suitability for military medical training overall.

During a weeklong TE event, 33 experienced military medics evaluated 27 medical simulations presented by industry vendors. Results are currently being analyzed. The medics also provided feedback on the evaluation criteria and methodology, which will be used to further refine the process of comparing capabilities for military medical simulation. Future work will continue the development of the evaluation criteria to recommend a set of standards for military medical simulation, which will provide guidance for developing medical training that meets operational needs.

Optimizing Dynamic Visualizations, Operational and Engineering Models for Today's Warfighter

CPT Logan Rash, USA • CDR Herbert Honaker, USN (Ret.)

23141

The communications complexities in today's battlespace continue to increase at an exponential rate. The demand for fielding new technology that works as intended is critical to mission success. Our Joint Force is anticipating and entering an era where our tactical and operational dominance is in question and considers the environment where the potential enemy can interrupt and impede our military operations. So often, the warfighter is left out of the initial planning phase for new technology and capabilities, ultimately leading to mission failure. We have found great success utilizing a suite of tools that fully integrate the analytical rigor and warfighters with detailed dynamic visualizations that pave the way for the two to co-exist within technological development.

By operationalizing Microsoft's Power Bi Dashboarding, we have been able to integrate old, new, and future capabilities that identify the operational "so what" providing end-users with a clear operational picture. We have modernized the way decision makers, warfighters, and engineers see the battlefield through detailed analysis, graphics, and the powerful capability of dynamic data visualizations to build an optimal Course of Action within multiple Joint Mission threads. Augmenting such software combines Mean Operating Scores (Data & Modeling), Quality of Service (Operator Expertise), and an operationally informed Model Based Systems Engineering process to enhance new technology turnaround times and product leveraging across the community of interest. Additionally, it will also save considerable funding through the creation of a more streamlined and accurate systems acquisition process in support of Testing & Evaluation, Simulation Exercises and optimized Platform-System configurations.

Finally, the paper presents a full operational picture with detailed proven analytics, dynamic mission threads, and operational benefit for Warfighters & Engineers. The overarching components outlined in the paper will offer the community with an essential and effective approach in bridging engineering solutions to successful operational outcomes.

Modeling and Simulation for Hypersonic Missile Threat Assessment

Randal Allen, Ph.D.

23146

Advanced simulation techniques are needed to develop hypersonic missile threat assessments, especially in a typical case of incomplete information. Current notional defense against hypersonic missiles lies somewhere between exoatmospheric ballistic missile defense and subsonic or supersonic cruise missile defense. With hypersonic glide vehicles or hypersonic cruise missiles, their trajectories lie within the atmosphere and, of course, travel at hypersonic speed – meaning a Mach number greater than five. Due to these partial overlapping threat assessment approaches, a novel synthesis of methods is required. To aid in this threat assessment, a digital twin missile model was built to simulate and parametrically estimate performance subject to uncertainties.

This paper presents how the digital twin model was built for simulation based on first-order, physics-based engineering equations of aerodynamics and propulsion, where threat assessment is measured in the form of range capability and other performance measures, e.g., kinetic impacts. The model was verified by checking each equation with example calculations and validated with three baseline missiles: the Harpoon turbojet-based antiship missile, the AIM-7 Sparrow solid rocket-based air-to-air missile, and the ramjet-based Advanced Strategic Air-Launched Missile (ASALM).

Finally, the paper presents results of an application of hypersonic missile threat assessment based on publicly available or interpretable information of the Russian 3M22 Zircon hypersonic cruise missile. Furthermore, the paper demonstrates the sensitivity of the unknowns (lift-to-drag ratio, specific impulse, fuel type, fuel weight, etc.) and how they impact confidence in range performance capability. Therefore, if intelligence assets are limited or available information is conflicting, risk-based decisions are enabled.

Adding Weather to Wargame Simulation

Hung Tran • John Wokurka

23151

Wargames bring together the two concepts of simulation and games to offer structured and rigorous environments where players can explore strategies, concepts of operations, and technologies across different levels of war. Simulations ingest military doctrine and performance data into their high-fidelity platform models. Then, using a game construct, players enter plans that are carried out by high-fidelity models in which outcomes are compared against objectives. The future state-of-the-art U.S. Marine Corps wargaming facility at Quantico is capable of multiple simultaneous games across multiple classification levels. The simulation environment attempts to be as realistic as possible to provide an immersed training experience comparable to a real-world battle. For instance, weather represents an important factor in determining the course and outcome of battles. Rain can slow the movement of a force, or wind intensity can alter the range of a weapon system. Environmental data, such as terrain, wind, precipitation, turbulence, and other meteorological parameters are examples of the limits of the weather condition profile of a simulated environment. Converting these weather parameter features into quantitative effects and impacts is not only computationally burdening for simulation systems, but also compromises the “fair fight” aspect of the simulation since each simulation system computed the weather effect differently. Therefore, the weather data must be transformed into effects and impacts to be effective. The challenge for wargame designers is to provide accurate and timely weather data to the simulation systems, but also tactical decision aids that relate the impact of the weather on systems performance. This paper examines the role of weather simulation in the USMC Wargaming capability. It describes how the historical weather data augmented by a dynamic weather simulation model is used in wargaming. Finally, it will evaluate how the simulated weather is translated into effects and impacts on the simulation systems during a wargame’s execution.

Creation of a Human-in-the-Loop Simulator Environment for Fifth Generation Stressor Research

Maykel van Miltenburg • Lodewijck Foorthuis • Rolf Zon

23180

The introduction of fifth generation platforms has led to a more information-driven air operation. It is characterised by the communication between different platform types within a mission and an increased operator autonomy due to improved information availability. This places new demands on pilots in terms of their cognitive capacity and could lead to specific stressful situations. Current research lacks understanding of the subtle differences between fourth and fifth generation stressors. Consequently, this requires additional knowledge on the interaction between stressors induced by fifth generation operations and human performance.

The fundamental challenge is to create an experimental set-up in which (1) multiple fifth generation platforms operate together and (2) the equipment to measure impact of stressors on the operator is integrated. A second challenge is to create scenarios that can be used in the set-up in which stressors can be generated and manipulated. This paper describes the design of an experimental set-up, which is suitable to measure the subtle differences between fourth and fifth generation stress.

A simulation set-up is developed, consisting of an F-35 and an MQ-9 simulator, both with human operators. To simulate multiple levels of stress, as well as fourth and fifth generation stress, mission scenarios are created. Functional Near-InfraRed Spectroscopy (fNIRS) and Electrocardiography (ECG) devices, in combination with the NASA Task Load Index (Hart, 2006), are used to measure the level of stress.

An experimental evaluation was carried out by former F-16 pilots using the developed missions and set-up. The evaluation results

showed that the simulation set-up can be used operationally and the equipment is able to measure the specific stress. Concluding, the set-up can be used for training purposes by an instructor to determine in real-time whether the scenario-specific task load should be altered. The developed set-up opens up possibilities for further generation specific stress-mitigation and training methodology development research.

Toward Next Generation Aerial Refueling Airplane Simulator Qualification

Michael Millington • Zack Kirkendoll • Brandon McCullough • James Cook, Ph.D. • Brain Morris

23186

The current standard for aerial refueling simulator qualification is the AMC document “Aerial Refueling Airplane Simulator Qualification, Rev. C” (ARASQ), dated 1 September 2009, initially modeled after the now outdated FAA advisory circular AC 120-40B, which has since been supplanted by 14 CFR Part 60 (2016). Since the last revision 13 years ago, there have been significant changes to aircraft, simulation technology, training methodologies, and manufacturer data rights.

Modeling and simulation of aerial refueling is complex and requires objective criteria to validate the solution at a sufficient level to significantly reduce aircraft flying requirements through the qualification of simulators. There are significant nuances for technical qualification requirements between receiver and tanker (levels C and D) and boom operator (levels 1 and 2) simulators. The current ARASQ standard is insufficient for modern aircraft capabilities (KC?46, KC-Y/Z), modern simulation and qualification methodologies, and next generation cost?effective lightweight lower-level training devices using technically mature commercialized technologies. Without next generation ARASQ, lightweight on-demand lower-level training devices cannot be leveraged for aerial refueling qualification or currency training as their simulation cannot be certified to prove no negative training.

This paper addresses next generation ARASQ innovative scientific research and analytical efforts to change the future of training the warfighter including:

- Receiver, tanker, and boom qualification tests and tolerances for next generation technologies, such as alternative visual systems from collimated displays
- Boom operator qualification validation tests and tolerances to better account for computer-controlled aircraft (CCA), such as fly-by-wire systems
- A pathway to utilize and qualify next generation commercial technology
- (e.g., virtual and mixed reality, controls, motion/haptics)
- A pathway to expand qualification levels for lower-level training devices
- Prerequisite trainer requirements and capability for distributed training (DMO) participation and interoperability
- A clear qualification pathway using alternative data sources (e.g., computational fluid dynamics) in lieu of instrumented aircraft pair data

Extending PNPSC Player Strategies with Continuous Firing Rates

E. Michael Bearss, Ph.D., CMSP • Mikel Petty, Ph.D.

23217

Organizations of various sizes and across various industries face an increasing risk from cyberattacks. Developing a deeper understanding of these attacks can facilitate the creation of more effective strategies to mitigate them. Petri Nets with Players, Strategies, and Costs (PNPSC) is an extension of Petri nets specifically designed to model cyberattacks. This formalism has been the basis for a long-running research program consisting of several interconnected research projects. Projects within that program include automatically generating PNPSC nets from the MITRE Common Attack Pattern Enumeration and Classification (CAPEC) database of cyberattack patterns, verification and validation of the models using several complementary methods, composing multiple PNPSC nets into models of realistic computer systems, and using machine learning to improve the strategies of players present in the formalism. Previously, strategies employed by these players consisted of a limited number of rates for each transition. This paper focuses on extending the machine learning of these player strategies to use continuous transition rates. Two deep learning algorithms, Deep Q-Network (DQN) and Proximal Policy Optimization (PPO) make use of function approximation to effectively improve player strategies when continuous rates are present. By using continuous transition rates, more granularity can be given to the real-world decisions represented by the transitions in the models. The training performance and effectiveness of developed strategies are compared to previous research using Monte Carlo reinforcement learning.

Constructive Simulation Limitations and Cloud Scalability

Jackie Zhang • Reese Gallagher • Cristhian De La Paz • Peter Drewes • Mike Baker • Brian McDonell, Ph.D.

23223

As the size and complexity of simulation exercises in the military training industry increase, traditional monolithic simulation training systems struggle to scale efficiently. While most legacy simulations were designed to support interoperability amongst multiple Live, Virtual and Constructive (LVC) training systems, adding training elements to a large distributed Integrated Training Environments (ITE) exercises have traditionally required purchasing and configuring new hardware and/or software, as well as lead time of 120+ days to prepare for exercises. This approach has proven with large capital expenditures into hardware and software required for large-scale exercises that skew innovation to cost ratios.

Constructive Simulation systems have been used to provide efficient computer-generated forces in large scale distributed exercises, such as the Army's One Semi-Automated Forces (OneSAF). OneSAF was developed to be a monolithic simulation system that does not support distributed multi-node and multi-core configuration and execution. Scaling large LVC exercise with multiple OneSAF instances at multiple locations with increasing cyber security requirements remain a challenge. With the US

GovCloud reaching maturity and security needed for military training exercises, it is a prime time to examine the future of scalable constructive simulations to support the PEO STRI Synthetic Training Environment (STE) architecture goals.

Our research and development effort compares the traditional scalability approaches of monolithic simulations with that of inherent scalability available within cloud-based solutions. We examine legacy simulations using OneSAF as a testbed, based on current acquisition processes to assess its ability to meet evolving LVC training goals. The result of this study will highlight potential configurations incorporating horizontal and vertical scaling technologies to analyze management costs and performance differentiators to the overall STE architecture, while prototyping the appropriate architecture to meet modern simulation and training requirements.

Unreal Oceans: Using Unreal Engine 5 to Simulate Realistic Maritime Vessel Motion

Brandon Rudolph • Matthew Thompson • Mark Thoreson

23240

This research leverages Unreal Engine 5 (UE5) to create a low cost, flexible test asset that drastically reduces the resources necessary to create high-fidelity simulations of real maritime vessel motion. Current techniques for modeling vessel motion are quite complex and require sophisticated physical representations of the vessel and the environmental conditions, which is very resource-intensive and narrow in scope. Combined with an existing motion platform, UE5 provides a method that can reduce the time and cost to generate realistic motion simulations. Because the UE5 environment is virtual, it can be adjusted to simulate numerous environments and vessels and can export the motion data for use on a real-world test asset. The test asset of interest is a portable Stewart motion base that provides high fidelity, simulated vessel motion for a variety of US DoD programs, including ordnance & weapon testing, electro-optic/infrared (EO/IR) stabilization testing, and target tracking algorithm development, amongst others. Increased access to this kind of high-fidelity simulation would benefit military programs with early developmental testing requirements and low technology readiness level (TRL) technologies that may be too high risk for full-up tests. The primary technical challenge of this effort is correlating UE5 wave simulations with realistic at-sea motion of a vessel. Once this relationship is established, the next step is to model additional vessels to ensure the virtual wave model is robust. Next, vessels are simulated in the UE5 wave environment to generate six-degree-of-freedom motion profiles that can be replayed on the motion platform system. In this way, any vessel motion modeled in UE5 can be converted into real-world motion rapidly, and a library of profiles can be generated at very low cost. The output of this effort can be compared to the traditional full hydrodynamic simulations and datasets collected at sea to evaluate the level of correlation to the real world.

ELMO (Electromagnetic Layer for Multi-domain Operations) Developing and Testing Activities

LTC Piergiorgio Ventura • CPT Salvatore De Mattia

23256

The electromagnetic environment is an essential element for the understanding and conduct of future military operations. Its transversal characteristic permeates the operational scenario in a multi-domain perspective and, therefore, the comprehension and management of this physical dimension is crucial.

The NATO Modelling & Simulation Centre of Excellence (M&S CoE) is conducting a project called “”ELMO”” (Electromagnetic Layer for Multi-domain Operations), which aims to create a synthetic environment for the virtualization of the so-called ElectroMagnetic Spectrum Operations (EMSO). In this context, M&S expresses flexible characteristics for the implementation of complex electromagnetic multi-domain scenarios, able to make visible in the scenario what is not visible or detectable in a real world environment. This feature would simplify the understanding of the main electromagnetic spectrum parameters and enhance the operational and informative characteristics which the electronic assets provide within the Electronic Warfare context.

The EM layer was built using the Software Tool Kit (STK), developed by the AGI Company, and MATLAB, developed by the Mathworks Company. The integration of the two tools was exploited to generate ad-hoc synthetic military components such as Jammers and Radar Warning receivers.

A specific scenario was then built in order to simulate a military EM environment, where the STK synthetic assets, such as satellites, radars and communication systems, interact with the military components developed in MATLAB. The EM layer generated by the MATLAB-STK integration successfully provides a comprehensive visualization over time of the entire electromagnetic spectrum on the battlefield.

The tests performed in a demo scenario with interacting objects virtually operating in a comprehensive EM environment proved the capability of ELMO to develop a complex framework suitable, not only for Commanders’ decision making, but also for capability Development and Experimentation.

Modeling & Simulation in Support of a Comprehensive CBRN Layer Development

LTC Piergiorgio Ventura • CPT Salvatore De Mattia

23257

Modelling & Simulation in support of CBRN and Environmental Protection has not been fully exploited to its maximum potential in the military domain; namely, Education and Training (Exercises), Support to Operations, Planning (Course of Action Analysis), Execution (Decision Support), Mission Rehearsal, Concept Development & Experimentation (CD&E) and Procurement. Many CBRN tools already exist, such as those providing models to simulate the dispersion of CBRN Agents, or the wearing of IPE during training. However, a comprehensive list of these types of tools, fully integrated to maximize its effectiveness, is still missing.

This innovative approach, which integrates existing tools and provides those not yet developed, represents a powerful M&S asset to fill the gap of this military problem. The purpose of this project was to develop and test, in a synthetic environment, a CBRN layer integrating the available tools, such as CBRN Analysis or Computer Generated Force Tools to maximize their capabilities and to perform missing CBRN related activities. For example, to determine the effects of chemical compounds on military units or developing a plug-in software to integrate the existing database and perform specific computations.

The CBRN layer has been developed using the SWORD simulation software developed by MASA Company and the CBRN Analysis developed by BRUHN NEWTECH Company. The scenario was built to simulate a synthetic CBRN environment with contamination and diffusion data. This data was provided by CBRN Analysis and the military assets were created by SWORD with the final objective of giving the Commander a comprehensive visualization of the CBRN framework in the battlefield.

A Flight-Representative Operational Cyber Test Environment

Jacob Pryor • Andrew Smilie • Tara Clayton • Steven Hildebrand

23260

An important aspect of modern cyber testing & evaluation is the immersion of the system under test (SUT) into an operationally relevant environment. This enables the SUT to be cyber-tested while performing a simulated mission at any time and place in the world while sitting safely in a test facility. In addition to this being a more realistic test from the perspective that the SUT avionics are in operational states with operational dataflows, this type of testing also enables the tester to assess the mission impact of cyber threats.

The Redstone Test Center has developed a flight-representative environment to immerse Army systems into this type of operationally relevant test environment. This environment is flight-representative in that it includes SUT stimulation with realistic Global Navigation Satellite System (GNSS) signals, inertial sensor signals, and physical air pressure to the SUT's pitot-static system. This environment has been integrated with live inputs from simulation sources such as One Semi-Automated Forces Distributed Interactive Simulation (OneSAF DIS), flight simulators, and other battlespace simulators and with pre-recorded flight data or flight simulation data. To date, these tools have successfully put several Army rotor wing systems into "simulated flight", including the CH-47F, UH-60M, and AH-64E.

This paper describes the issues and challenges associated with developing this simulation environment and how these challenges were overcome. Of particular interest were the challenges involved with integrating low-resolution data sources with GNSS and inertial data simulators that require high-resolution data by using dynamic feedback-control theory and analysis methods. The chosen solution integrates both off-the-shelf and custom hardware and software to create high-fidelity SUT input signals from any data inputs agnostic of the input data quality or type. Additional SUT stimulation inputs will continue to be developed and integrated with additional Army systems such as UAVs, ground vehicles, and munitions.

Techniques for Simulating Data Visualization of the Digital Patient

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23275

Volumetric rendering has become a reliable tool to perform image analysis and diagnostics. As the adoption of 3D medical imagery grows, enhancements are needed to increase the comprehension of patient conditions.

We present an expansion upon existing methodologies for volumetric rendering. We will present a literature survey that describes existing algorithms and methods and will highlight our contribution to the technology. Our approach combines the following techniques into a single gaming environment:

- Volumetric rendering within VR (Virtual Reality) for intuitive interaction with simulated patient data
- Improved human anatomy representation with real-time manipulation of depth and shadows
- Simulation of x-ray appearance and density coloring for data visualization options
- Investigation of data relationships with the overlay of multiple datasets for data fusion

this paper presents a study on the success of these combined techniques to better evaluate anomalies in medical data.

Viewing medical data in VR empowers the observer with a better understanding of the data's relationships. The digital patient can be inspected from all angles in relation to multiple scan types. This observation practice is computationally expensive; using VR to interact with rendered volumes increases the need for performance enhancements. Our approach addresses optimization methods necessary to perform the listed techniques and maintain framerates to provide a quality user experience.

To effectively examine our approach, a use case study will be performed. The study will use a specific medical condition understood to be historically limiting to visualize and analyze using traditional methods such as coronary artery disease (CAD) or Chiari Malformations. Healthcare professionals trained in medical imaging will analyze and interpret datasets affected by the condition. They will perform this analysis with and without our methods. The results will be used to showcase the potential diagnostic benefits of our volume rendering workflow for medical modeling and simulation.

Integrating New Engagement Types in Live Training Exercises

Tagg LeDuc • Julie Kent, Ph.D. • Marwane Bahbaz

23279

Integrating geographically adjudicated devices, such as mortars, into a laser-based Live Training environment necessitates a change in how damage is adjudicated compared to point-to-point targeting of lasers. Currently, indirect fire is simulated centrally through the exercise control with battle damage assessment being pushed to the affected trainees. This approach reduces training realism because the soldiers are not provided with an origin in the field or the ability to counter-fire. There have been numerous

attempts to create devices that would trigger laser receptors or otherwise imitate an area effect response, but they have not been incorporated into US combat training centers. Advancing technology has introduced new mechanisms to simulate weapons which may have an area of effect and make use of those models in Force-on-Force collective training.

This paper discusses changes to the live environment to more fully exercise brigade combat team capabilities using advanced mortar, grenade, and mine simulators. The approach used to develop and test the devices is discussed along with plans for continuing to integrate devices into the existing Live Training environment.

Comparison of Visualization Technologies to Support RCAF Training Modernization

Maj Jason Munn • Jerzy Jarmasz, Ph.D. • CAPT Daniel Deluce

23284

The Canadian Armed Forces (CAF) have initiated a major Reconstitution effort to strengthen capabilities needed to ensure operational relevance in the current and evolving security environment. As part of this, the Royal Canadian Air Force (RCAF) is undertaking a major training system modernization. This transformation looks to leverage emerging training technologies to support more flexible, individualized and streamlined training for its personnel.

In order to support the RCAF's training modernization, the RCAF Aerospace Warfare Centre (AWC) is seeking to develop evidence-based procedures for the adoption, application and maintenance of the RCAF's modeling & simulation (M&S) capabilities. In addition, Defence Research and Development Canada (DRDC), as part of its research program on Training for the Future Operational Environment (TFOE), is investigating how to improve the adoption of training technologies in the CAF. DRDC's investigations have identified a number of organizational and human factors that impede effective training technology use. One of those factors is a general lack of evidence on the effectiveness and usability of emerging training technologies, consistent with the RCAF AWC's experiences in this area.

Accordingly, the RCAF AWC and DRDC are partnering to conduct experimental studies examining M&S technologies key to the RCAF AWC's capability for conducting distributed joint and coalition collective training. The first study, reported here, examines the suitability of different visualization technologies in the context of distributed collective training. The study compares the effects on performance (e.g., track integrity), workload and usability of three different visualization configurations (conventional monitor, curved wide-angle monitor, mixed-reality headset) in simulated air patrol tasks by experienced fast jet pilots. The findings of this study and their implications on visualization technology use are discussed in the context of the RCAF AWC's efforts to modernize its distributed coalition training capability and DRDC's activities on supporting training technology adoption in CAF.

Automated Building Corner Detection for Validating 3D Point Cloud Data

Amy Neuenschwander • Jeff Perry • Lori Magruder

23286

The utilization of high-resolution 3D point cloud data is becoming more common to a variety of DoD applications and many photogrammetric data sets are collected via small UAVs. Although these data are common, they do not always contain information regarding their geolocation uncertainties. Determination of the geolocation accuracy of any 3D data set typically involves the labor intensive process of an analyst having to identify and extract the coordinates for building corners or other ground targets. Here, we present an automated 3D building corner finder that can be used to determine the global accuracy (i.e. the geolocation offsets) of high-resolution point cloud data. First, building points are identified in both the test and reference point clouds using an automated feature extraction process. Next, building points are regioned into unique buildings and matched between data sets based upon centroid coordinates. Then, an iterative 3D bounding box is passed over each unique building to isolate the building roof corner locations. In addition to the corner finding, our method identifies center ridgelines of rooftops which are useful for estimating rotations about the X or Y axis. Geolocation offsets are calculated on a per-building basis. The output from this process can be directly ingested into the generic point-cloud model (GPM) for the high-resolution data.

Incorporating Navigation Effects into Synthetic Environments for Improved Cyberspace Training

Omar Hasan, Ph.D. • Andrew Mendoza, • Jeffrey Welch • Robert Burch • J. Allen Geddes

23295

Global Navigation Satellite Systems (GNSS) such as the Global Positioning System (GPS) are used by military organizations for precise positioning, navigation, and timing (PNT) services. GNSS systems, however, are vulnerable to attacks including jamming and spoofing. These attacks can block GPS signal reception entirely or can cause users to appear at incorrect locations, resulting in operation disruption and safety issues. For example, during the current Russian-Ukraine war, Russian forces have faced widespread GPS disruption caused by long-range drone-based GPS jamming attacks by Ukraine. The modern warfighter is vulnerable to such PNT-based attacks, and as a result needs to train on identification and mitigation of PNT-based attacks to retain full military operational capabilities in the modern battlespace.

To support multidomain operations (MDO) training in this complex operational environment, the Army's Live, Virtual, Constructive, and Gaming (LVC&G) training systems need to incorporate realistic PNT disruption effects. However, in many cases, current LVC&G systems lack sufficient modeling of the GPS satellite constellation. In this work, we describe our initial efforts to provide an architecture to integrate high-fidelity modeling of GPS signal information into the synthetic training environment. We established an architecture, toolset, and approach to communicate GPS signal information produced by the GPS Interference and Navigation Tool (GIANT) into the simulation driven training environment, where

GPS jamming and spoofing effects are placed on simulated GPS receivers. The Cyberspace Battlefield Operating System Simulation (CyberBOSS) system provides an integrating architecture between GIANT and simulated GPS receivers in the One Semi-Automated Forces (OneSAF) system. This approach supports scenarios that incorporate detailed effects of operating in a GPS-degraded environment, including disruption of navigation and weapon fire tasking. We discuss the next steps to be taken to further integrate detailed PNT modeling into simulation-driven exercises, including future coordination with live training participants.

Cyber Reactive Adversary Framework for Training

Sean Guarino • William Norsworthy • John Steigerwald • Dorsey Wilkin • David Kelle

23303

Networks have become a critical background for military operations as adversaries and hackers become increasingly prolific and proficient at cyber warfare. Despite this, cyber training has remained focused on large-scale exercise that can be expensive and time-consuming, and ultimately too infrequent. A key element that drives this decision is the need for human experts to control adversary cyber operations forces (OPFOR). These experts can be difficult to obtain, and, when available, the goal is often to leverage their time to the greatest extent possible, driving these complex events.

This paper describes ongoing work to develop an automated cyber adversary framework that enables the insertion of dynamic adversary behaviors into a live training environment, alongside tools for instructors and red cell operators to understand and customize the training experience provided by the automated adversary. Our solution combines: (1) an adaptive adversary framework that uses reactive behavior modeling to provide realistic, dynamic, and customized adversary behavior for meeting training objectives; (2) a cyber execution engine that integrates adversary agents with tools in the network environment, translating high-level adversary activities into appropriate low-level attack actions; and (3) an instruction support suite that provides tools for configuring, tracking, adjusting, and revising adversary behaviors to provide effective training. To enable rapid application across a wide range of adversaries, we have developed a behavioral template that can be adapted to include different types of attack tools, methods, and tactics. We will describe and demonstrate our application of this template and framework to model several advanced persistent threats identified in MITRE's ATT&CK framework. Future work is focusing on extending this framework to support a wider range of adversaries and adversary tactics, and integrating this evolving training environments such as the DoD's persistent cyber training environment (PCTE).

A Generic Missile Defense System Model for Use in Cybersecurity Vulnerability Assessments

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23306

This paper discusses a generic missile defense system model used for examining impacts of cyber-attacks against the system. As cyber-warfare has become nearly ubiquitous in military theaters throughout the world, there exists a growing need to improve the cyber resiliency of defense systems. However, analysis of the potential vulnerabilities of these systems presents a multitude of barriers when such analysis necessitates the use of the physical system itself. For missile defense systems, barriers range from accessibility of the systems to the risk of physical harm. Virtual models, such as the one outlined in this paper, provide invaluable, low cost, repeatable analysis.

The model is designed to be modular and scalable, allowing a wide variety of missile defense systems and scenarios to be emulated. Modeling each component's physical, state, and networking characteristics to a high level of fidelity allows for the identification and exploitation of vulnerabilities and observation of the consequences within the system. The model was developed using open source information and insight from missile defense experts and incorporates three types of components. Two of these, the Radar and Launcher, allow a variable number of each to be included in a given simulation. Additionally, a single Command and Control unit interacts with and instructs each Radar and Launcher. These components form isolated nodes on a network that employs communication protocols representative of those in real systems. A Simulink model provides physical data of incoming ballistic threats and launched interceptors, which stimulates and interacts with the system in real time. The model has been used to analyze the propagation of malware and its effects throughout missile defense systems. The data generated by logging component states and capturing network traffic during this analysis has informed the development of machine learning algorithms for the detection of cyber-attacks.

An XR Authoring Tool for Customizing Aviation Weather Educational Content

Kexin Wang • Jack Miller • Jiwon Kim • Michael C. Dorneich, Ph.D. • Eliot Winer, Ph.D.

23309

In 2020, there were 212 fatalities in civil aviation activities, with 205 of them under the category of General Aviation (GA). Additionally, 17 out of 23 GA accidents were weather-related. To mitigate this issue, researchers have employed XR technologies to improve GA weather education and training for pilots. However, since the created XR content only contains limited pre-defined scenarios, it is unable to address the wide range of weather-related conditions a GA pilot will encounter. Thus, a gap exists between what instructors need and the tools available to them. Flight instructors with expertise in aviation weather could create more, and varied scenarios, but they most likely do not have the XR development knowledge required (i.e., computer graphics and coding). Alternatively, developers who routinely create XR content often have little knowledge about aviation weather. A simple to use XR authoring tool is needed to allow customized educational content to be created by aviation weather instructors.

Formal interviews of flight instructors were conducted to understand a range of issues such as desired educational outcomes, features, and instructor technical competencies before software development began. Based on interviews, requirements were developed for an authoring tool to develop customizable

weather-related flight scenarios (i.e., clouds, precipitation, high winds) to practice pilots' decision-making. The authoring tool was implemented with a modular thunderstorm cloud model (i.e., particle systems with customized graphics shaders) and provides instructors features to control duration, elevation, and size. In addition, the tool enables authoring in 2D with a 3D visual preview that non-graphics experts can readily understand. To enhance usability, the authoring tool provides customizable layers of mesh models, textual overlays, and adjustments for position and orientation to create clear visual time-based scenarios of weather-related flying activities. The tool was evaluated by flight instructors on a range of measures with overall very positive results.

A Structure for Representing Critical Infrastructures

Edward Carmona • Freddie Santiago

23335

As per directive PPD-21, and as the war in Ukraine has exposed, models and simulations need to incorporate Critical Infrastructures (CIs) to ensure using them results in effective training. Historically, CI has been minimally included in legacy training systems because modeling them correctly is tremendously complicated. CIs challenge the conventional representation of the terrain in that they require more than a description of physical attributes of structural elements (e.g., location, shapes, materials, and visual attributes). CI models must describe how a given structure is linked to other structures and how they are interdependent in terms of function and use. Many aspects of representing and handling CI is difficult, such as reasoning about non-local, far-reaching, first-order ripple effects caused by damage to the intended function of a structure. Even more difficult is taking account of second- and third-order impacts due to unintended functions and uses. Thus, it is not enough that CI structures and their linkages appear in the terrain; the runtime system must also preserve the coherence of the terrain by accounting for the cascading results of local damage to these structures.

In this paper, we describe a flexible data model that can be used to assemble complicated CI networks. This novel solution invites the cooperation between static terrain data generators, runtime, and modeling subsystems to architect the CI. We also present a solution that maintains coherence of the CI network via a runtime engine, while leaving the modeling to the simulations, by adapting Leontief's Input/Output classical model. This prize-winning approach has historically been employed by economists to determine the state of an infrastructure network given changes in demand for the goods and services the infrastructure provides. As a use case, the paper demonstrates this methodology using a realistic specification of a megacity's infrastructures.

Automated Generation of Accurate 3D Building Interiors: Lessons Learned and Challenges

Aaron Katzman • Joseph Moran, Jr.

23338

Future military engagements are increasingly likely to occur in dense urban environments, accelerating the need for accurate representations of buildings, both exterior and interior. A variety of formats are required to support training, operational, and intelligence communities. Current data collection methods and automated data processes that generate 3D synthetic models are not mature enough to handle the complexities of dense urban environments.

State-of-the-art drone technology enables the automated collection of ground-truth exteriors and solves some of the problems with building exterior generation, using photogrammetric techniques and laser scans from air or ground-based sensors. These techniques, however, do not adequately apply to interior collections.

Modeling a building interior presents a complex problem to the modeling and simulation community. The traditional approach to modeling building interiors, by hand, using CAD or other 3D modeling tools is costly, both financially and in turnaround time. This especially true for multi-story buildings or buildings with unusual geometry. Without an interior paired with the exterior model, there are limitations to the situations and scenarios where a building model asset can be used. Every collection method presents unique advantages and disadvantages impacting its value to the automated processes employed to create an interior model.

Our research suggests that a broad spectrum of techniques and algorithms be employed to create interior models, rather than to rely on a single automated collection and processing mechanism. In this paper, we discuss how a combination of commercial and open-source software, organized in a pipeline, incrementally improve, and optimize interior geometry. We also discuss lessons learned from a) data collection analysis; b) various data formats; and c) machine learning experiments that provide contextual clues. Lastly, we discuss how automation is leveraged to correct data collection and generation errors, and to derive complex metadata for interiors.

Real-Time Surface-to-Air Missile Engagement Zone Prediction Using Simulation and Machine Learning

Joao Dantas • Diego Geraldo • Felipe Medeiros • Marcos Maximo • Takashi Yoneyama

23357

Surface-to-Air Missiles (SAMs) are critical components of air defense systems, and defining their engagement zone (EZ), which is the region of airspace where they can engage and destroy targets, is essential in the modern warfare context. The EZ's volume and shape vary based on factors such as the missile's propulsion and guidance and control systems, as well as the target variables such as speed, altitude, off-boresight angle, and evasive maneuver pattern. As a result, accurate and efficient simulation tools are essential for predicting and evaluating SAM performance.

This paper uses a custom-made simulation tool to analyze SAM EZ performance, focusing on using machine learning techniques to reduce the computational time required for generating the simulation responses. The proposed method involves training supervised machine learning techniques on a dataset of pre-computed SAM EZ simulations, allowing the prediction of the EZ performance for new input parameters. The trained model can then be used to generate EZ simulations quickly and accurately, allowing for rapid analysis of different scenarios and configurations.

The paper also discusses the limitations and challenges of the proposed method, including the need for large amounts of training

data and the potential for overfitting. Additionally, the paper highlights the importance of ongoing evaluation and refinement of the simulation tool to ensure its accuracy and relevance.

Overall, this paper demonstrates the potential for machine learning techniques to improve the efficiency of SAM EZ simulations, enabling air defense planners and operators to make more informed decisions and optimize SAM system performance in real time.

Evaluation of Open-Source Data for Gray-zone Operations Decision-Systems

Robert Ducharme, Ph.D. • Brian Mills • Jay Freeman • Colby McAlexander

23370

Gray-zone activities?behaviors and/or actions potentially leading to, but below the threshold of armed conflict? executed across actors' instruments of national power present significant national security and global stability challenges. Successful gray-zone maneuver depends on an actor's ability to model, then implement effective strategies whilst managing the associated risks and chaos of possibly destabilizing activities. One approach to modeling the evolving nature of global competition and conflict is examining the history of international relations encoded in multiple Conflict and Mediation Event Observations (CAMEO) open-source databases. An exemplar – the Global Database of Events, Language and Tone (GDELT) project is 55TB of events and related data from public news sources accumulated for four decades. This paper examines the feasibility and suitability of this data as a means for decision-makers to explore complex, dynamic gray-zone phenomena, anticipate competing incentives, and assess consequences of choices. There are four facets to this proposed approach. First, it will be shown gray-zone news events fall on a Pareto distribution in terms of the number of mentions each gets in the media. Second, Reflective Thematic Analysis (RTA) is used to extract relevant data from GDELT to train statistical topic models for actor behaviors. Thirdly, results?including newsfeeds and thematic signatures?are generated for two actors over the first four months of 2023. Regarding data quality it will be shown that filtering events with low mention counts can be used for data conditioning, but unfiltered and filtered topics appear statistically similar so that strong filtering is not usually worth the information loss. Finally, we discuss utilizing open-source intelligence (OSINT) for potential model generation for wargaming capabilities. In this, emphasis will be placed on the usefulness of mention counts for cost-benefit-risk analysis to aid decision-making as well as the power of RTA to adapt OSINT to alternate analyst frameworks.

Using Virtual Reality to Connect Military Families Together: A Diary Study with the Virtual Family Room

Joshua Baldwin • Andrew Rukangu • Kyle Johnsen, Ph.D. • Sun Joo (Grace) Ahn, Ph.D.

23388

Virtual Family Room is an immersive virtual space that allows physically separated military families (e.g., on deployment) to interact with each other through avatars as if they were together, sharing the same space. Preliminary analyses indicated that Virtual Family Room could help maintain family cohesion and address the difficulties introduced by physical distance by encouraging families to continue their rituals and shared experiences. The current study aimed to provide new insights on the efficacy of Virtual Family Room and on the impact that the Virtual Family Room has on family communication practices among military families. The study also demonstrated the feasibility of using the Virtual Family Room over time, outside of the laboratory, in a naturalistic setting. A total of ten military families with children (between ages 6-18) were recruited through the National Military Family Association and asked to communicate as often as possible with Virtual Family Room (via the VR headsets) for approximately 8 weeks. After each interaction session, families completed online diary entries. The online diaries included prompts to discuss their communication experiences within the Virtual Family Room and the impact these experiences have on their family relationship. The questionnaire results indicated that respondents felt a significantly high level of shared reality, positive communication, and cohesion with family members. Open-ended responses indicated that the quality of the experience varied between location and internet quality. However, those that were able to overcome technological hurdles together as a family expressed close and fun bonding experiences within the Virtual Family Room. Additionally, families were more likely to engage in creative and exploratory activities with subsequent usage. Together, these results indicated the ways in which virtual spaces can help sustain cohesion and well-being when families are physically separated. However, there are still technical challenges to broadly implementing VR for family communication.

Iterative and Incremental Validation of Simulation Conceptual Models

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23398

Model validation is a technically challenging task for simulation projects. One-shot validation of conceptual models is not practical for most simulation system projects due to the inherent logical complexity of individual models, interdependencies between models, and the diverse viewpoints of the stakeholders.

Fidelity, in particular, is an issue that permeates these characteristics. The required level of fidelity is largely determined by the expectations of the users and sponsors about the simulation system, e.g. the kinds of analyses that can be accomplished. Tacit assumptions that are implicit in the stakeholder viewpoints and that underlie all modeling activities gradually become explicit through model validation activities. Moreover, harmonizing assumptions as they become explicit and clearly spelled out requires negotiations, which take multiple rounds of exchange.

Therefore, it is often difficult for stakeholders with diverse viewpoints to align on rules, boundaries, methods and constraints, and assumptions throughout the validation process. Therefore, model validation, by nature, is a multiple-stakeholder activity, that requires a specifically defined process per project, so that all

aspects of the activity, varying from stakeholder management to application of technical validation methods, can be executed in gradually increasing levels of agreement and harmony.

In this paper, we argue that the aforementioned difficulties can be relieved by the establishment and application of iterative and incremental approaches for model validation activities throughout a project. Specific practices have to depend on the specifics of the project, such as model fidelity requirements, availability of field data for validation activities, accessibility of subject matter experts, etc. Nevertheless, a simulation system development project can highly benefit from a custom-defined iterative and incremental process for model validation, inspired by corresponding software development principles.

Virtual Reality-based Medical Simulation for Pre-Hospital Space Medicine Care: VALOR PHSMCC

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23414

Introduction. Human space flight support (HSFS) has been a DOD mission since the establishment of NASA in 1958. Medical support is a key component of this mission, including the provision of urgent and emergent healthcare to astronauts and other space flight personnel during routine operations and mishaps.

Providing high-quality care in these circumstances requires training for demanding, high-intensity, rare operations. However, full mission profile (FMP) training for the mission is highly expensive and logistically complex, requiring medics and equipment to be dropped into the ocean for simulated capsule recovery. In this work, we developed an immersive virtual reality (IVR) medical simulation capability to broaden access to FMP-style simulation training across the full spectrum of special warfare medics who may be deployed for the HSFS mission.

Methods. An interdisciplinary working group consisting of emergency physicians, space operational medicine experts, instructional designers, and IVR engineers was formed. The working group first determined a set of space medicine scenarios to implement in IVR. Then, a set of mission-specific platforms and environments with associated sets, kits, outfits, and equipment were specified. The specified materials were then implemented and iteratively refined using a previously developed IVR platform (VRMSS, SimX, Inc.).

Results. Ten scenarios ranging from normal operations to severe injuries and mishaps were specified, implemented, and refined within the IVR system. Virtual capsule replicas were developed in pad and ocean recovery environments. Aerial and naval platforms were implemented, including the C-130, HH-60, Rigging Alternate Method Zodiac, and Advanced Rescue Craft. A complete equipment and outfit set was implemented, including 175 tools and equipment sets.

Conclusions. A comprehensive IVR-based medical simulation capability for space operational medical support was developed for virtual FMP training. The resulting capability is currently being integrated into special warfare medicine training and may also have applicability to civilian commercial space flight programs.

Enabling Multi-Domain Operations through Simulation Services

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23421

As the United States (US) Department of Defense continues to implement the concept of Multi-Domain Operations (MDO), our simulation tools must focus on solutions that enable rapid and continuous integration of all domains of warfare in a multi-national context. As the focus of national strategies turns to Large-Scale Combat Operations (LSCO), our technical requirements evolve towards the need for scalable tools that are accessible by a large number of users in a distributed environment. To that end, the US Army is exploring how the concept of Modeling and Simulation (M&S) as a Service (MSaaS) can meet this need through the ability to enable more flexible simulation environments that can be deployed and executed on-demand.

This paper discusses insights gained through collaborations within the US Army, with the US Air Force and with the North Atlantic Treaty Organization (NATO) M&S Group (NMSG) – 195 “MSaaS Phase 3”. It details how: 1) the concept of Sensor as a Service provides broad applicability and availability across numerous Army M&S Communities, including Acquisition, Experimentation and Test and Evaluation; 2) the One Semi-Automated Forces (OneSAF) program office has implemented a Perception Service that allows simulations to share high fidelity modeled components as a registered provider and consumer of those models within the Bifrost server; and, 3) the US Air Force Advanced Framework for Simulation, Integration and Modeling (AFSIM) can operate in an MSaaS environment through a demonstration that includes Electronic Warfare sensors, attached to an Unmanned Aircraft System (UAS) platform, interoperating with OneSAF ground forces, in an MDO environment. Finally, we discuss how these excursions are both benefiting from, and informing, NMSG-195 in order to mature MSaaS to meet the technical requirements being driven by the need to simulate LSCO.

Immersive AI Assistance During eVTOL Multi-Agent ATC Traffic Routing

Jean-Francois Delisle

23426

Advances in artificial intelligence (AI) such as natural language processing (NLP) and reinforcement learning (RL) are enabling a resurgence in immersive flight training for both instructor-led and self-paced training, such as with immersive MR/VR (Mixed Reality/ Virtual Reality) devices.

Introduction of MR/VR will likely require dialog management and command & control capability in a self-paced learning context. Adding an NLP-based cognitive agent acting as a virtual instructor and co-pilot provides the required immersion level to broaden the spectrum of self-paced learning during the pilot's learning journey.

Pilots receive instant feedback on their performance, explanations of the communication procedures, and progress tracking as they develop their skills.

Accent-tolerant advances in speech interaction are used to recognize radio transmissions from the ownship using NLP on a flight training knowledge base. Conversation agents increase student immersion and offer more realistic workloads by fully automating the ATC (air traffic control) function, freeing up the instructor to focus more on core observation and training tasks, and allowing more automated flying without an instructor for MR/VR simulation training.

The complexity of real-world ATC communications, such as conditional clearances and instructions that include give-way, can only be simulated when the ownship is fully embedded with other traffic. An AI ATC module leverages a collaborative multi-agent framework to manage air traffic during real-time MR/VR flight simulation in a synthetic urban environment scenario.

This paper will explore issues around robustness in reinforcement learning and evolutionary optimization problems, alongside new results in collaborative multi-agent systems. These outputs will provide further results in nonlinear function approximation (e.g. deep neural networks) and optimization methods in stochastic environments. It will also study human factors during immersive Mixed-Reality training of emergency scenarios with an AI agent integrated into an eVTOL (electric Vertical Takeoff and Landing aircraft) flight training simulation and operation platform.

Simulating Civil Security Activities in Stability Operations

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23448

Civil security activities are an essential aspect of stability operations that address threats and reduce violence to establish a safe environment in which civilians can freely move about and carry on normal activities. When addressing threats to civil security a military force must balance the use of nonlethal and lethal force in a way that best meets mission objectives. However, civilians may respond in unexpected ways to varying uses of force, making this balance difficult to achieve.

Researchers at the Naval Postgraduate School's Center for Modeling Human Behavior have developed the agent-based simulation Workbench for Refining Rules of Engagement against Crowd Hostiles (WRENCH) to address this challenge. WRENCH models a security force carrying out civil security activities, addressing any emerging threats via the use of both nonlethal and lethal weapons. WRENCH also models realistic complexities of civilian individuals and groups that drive crowd behaviors and responses to the use of force. In WRENCH many aspects of the security force are user-specified, as well as the selection of the set of available weapons and the specification of tactical rules of engagement to govern weapons use. Many aspects of the civilian population are also controllable.

In this paper we first provide a brief overview of WRENCH's design and capabilities in the context of securing an urban area and compound and describe key output metrics of interest. We then present an experiment that explores the effects of the use of different types of weapons under different sample rules of engagement across several different civilian scenarios. And finally, we discuss insights from both the experiment results analysis and the challenges associated with model design and validation efforts.

Numerical Study of Ammonium Nitrate/ Fuel Oil Detonations for Large Scale Pattern of Life Simulations

Mike Theophanides

23457

Next generation frameworks have been developed to support large-scale pattern-of-life simulations. These simulations are paramount to assess the consequence of hazardous events in urban environments and to develop effective emergency response strategies to these events. CAE has been prototyping large-scale pattern of life simulations in real time, human-in-the-loop operations for concept development, course of action analysis, and training. The simulation of bomb explosions is a critical component of emergency response simulations and provides valuable insights into the potential effects of an explosion on infrastructure and populations. This paper will report three simulation scenarios of Ammonium Nitrate/Fuel Oil (ANFO) explosions in urban areas of Tallin, Estonia. The blast simulations were simulated with Blastfoam, a compressible flow solver for high-explosive detonations and airblasts that integrates easily with other computational fluid dynamics (CFD) software such as OpenFoam. Detonations ranging from 5,000-10,000 lbs of a fertilizer lorry in the areas of Tallin's Freedom Square, the Stadium and Town Square were simulated. The simulations considered the variability of explosive charge, surrounding infrastructure including buildings, terrain topology and street corridors. The framework was integrated within CAE's core servers, including the importation of 3D urban geometry from CAE's visual databases and CAE's Single Synthetic Environment (SSE) server for visualization of the blast pressure waves. A 76-core Azure Virtual Machine was used for meshing and running the CFD solver for up to 1000 milliseconds. The blast pressures imported into the SSE server converted spatial and temporal distributions of pressure data into probabilities of human casualties. The paper will demonstrate the effectiveness of using advanced frameworks and pattern-of-life simulations as a crucial tool for training emergency responders and evaluating the efficacy of response plans.

Leveraging Modeling and Simulation in Support of Project Convergence

Brian Parrish • **Pedro Quinteromercado** • **Ed Hua**

23473

Project Convergence (PC) seeks to enable Joint Force experimentation with speed, range, and decision dominance to achieve overmatch and inform both the Joint Warfighting Concept and Joint All Domain Command and Control (JADC2). PC leverages a series of joint, multi-domain engagements to integrate artificial intelligence, robotics, and autonomy to improve battlefield situational awareness, connect sensors with shooters, and accelerate the decision-making timeline. The use

of Modeling and Simulation (M&S) in PC has become a critical component to augment live operations and support achieving experimentation objectives.

This paper starts with an overview of the M&S evolution in PC since its inception in 2020. PC20, without a M&S component, focused on converging 30 live technologies in a sensor-to-shooter use case. PC21 applied M&S for the first time to support Integrated Air and Missile Defense (IAMD), fires, and stimulation of Joint C2 systems. PC22's M&S supported two operational scenarios with seven use cases each, and over 110 technologies.

The focus of the paper is the two M&S scenarios in PC22, where the experimental design centered around multi-domain operations, maritime and land-based scenarios spanning operational and tactical levels to address the learning demands from Army, Joint, and Combined partners. Scenario A was maritime-centric that established IAMD at the operational level, delivered Joint Fires, employed Space Control Operations, and assessed sustainment distribution capabilities. Scenario B was land-centric that integrated deep sensing to penetrate anti-access, area denial environments, delivered Joint Fires and effects to enable freedom of maneuver, employed a Multi-National Division equipped with autonomous systems using Mission Partner Network, and employed predictive logistics capabilities and medevac technologies.

Finally, the paper identifies key M&S insights, network considerations, data collection, open issues, and present challenges that need be addressed to improve PC experimentation.

TRAINING

BEST PAPER

Contextualizing Cyberspace Electromagnetic Activities (CEMA) in Multi-Domain Operations (MDO) Through Playbooks

COL Chad Bates, Ph.D. • Jacob Cox, Ph.D. • Clark Heidelbaugh • Jim Ruth • Tim Friest

23179

Modern warfare mandates that adversaries have the opportunity to engage one another in Multi-Domain Operations (MDO) that span land, maritime, air, space, and cyberspace. To do so effectively, warfighters must not only integrate an array of capabilities, but must also synchronize cyberspace operations (CO) and electronic warfare (EW) across all domains and lines of operations to gain information advantage. To achieve this approach, commanders and staffs must integrate and synchronize CO and EW with other military capabilities (e.g., intelligence, signal, information advantage activities, and fires) through cyberspace electromagnetic activities (CEMA). However, this is an area of simulations and training that is searching for a viable solution. U.S. Army doctrine reveals little about how commanders and staffs envision CEMA tactics and actions working in combination with kinetic operations, and Warfighters struggle to visualize the operational environment through the lens of CEMA. As an initial step to addressing this problem, we developed a CEMA MDO Playbook for Modeling & Simulation that demonstrates how cross-domain capabilities, such as EW, CO, maneuver, and fires, can introduce dilemmas for the enemy while enabling friendly forces to conduct operations in degraded, disrupted, and/or denied operational environments. It includes lessons learned and identified gaps from an ongoing pilot with students and instructors at the U.S. Army War College to adapt the playbook as a training aid for visualizing the role of CEMA in MDO. The playbook can also assist teams to create training exercises or experiments with CEMA effects by integrating known simulations with plays from a common reference booklet. In the future, we envision a playbook supporting visual mappings of blue, red, and gray entities with their activities (CO and EW), actions, and impacts within training simulations and other events.

RFID Sensing and Analytics to Improve Team Training

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23103

Law enforcement and military operators are intensively trained and evaluated on their taskwork skills during room clearing procedures (e.g., speed of room entry, firing position, firing accuracy; Salas et al., 2008). As these teams become expert in their procedures, teamwork skills and processes (e.g., team coordination, backup behaviors, shared situational awareness) become critical factors in their ultimate performance and error avoidance (Salas et al., 2001). Extant research has demonstrated how various unobtrusive sensors can be used to evaluate teamwork skills and processes (Dubrow et al., 2017). For example, data collected from RFID tags, such as physical location, proximity to team members, speed, and orientation can be used as proxy measures for shared situational awareness, effort, and coordination (Feese et al., 2013, 2014; Kranzfelder et al., 2011). The current paper provides a technology demonstration of how unobtrusive RFID data collection, coupled with visualizations, analytics, and live video feeds, can be used to help improve teamwork training in expert teams. Lab data of individuals replicating publicly available standard operating procedures for room clearing in a shoot house are used to show how instructors may use the system during teamwork training sessions to help accomplish training objectives. Metrics such as physical distribution of Operators, entry speed, and orientation are used as proxies for teamwork states and processes including coordination, effort, and shared situational awareness (Feese et al., 2014; Kranzfelder et al., 2011). The paper demonstrates how data collected from RFID tags and cameras can be used to provide immediate replay of metrics, visualizations, and video to show changing Operator locations and orientations to augment current instructor training methods to meet teamwork training objectives.

The Coast Guard Investigating Officer Course: An Analysis and Redesign Using Immersive Technologies

LCDR John Botti, III

23119

The COVID-19 pandemic impacted a wide range of military operations. However, training centers, whose operational model centers around students from across the country traveling to a single location for resident courses, were significantly impacted. To cope, the delivery of many courses was rapidly transitioned from resident to remote by way of video conferencing. Such was the case with the Coast Guard's Marine Casualty Investigating Officer Course (IOC).

Yet until recently, there was no tool available to analyze and compare the impact of this transition on the course's immersiveness and educational fidelity. Enter Ruscella's and Obeid's (2021) Taxonomy for Immersive Experience Design. The taxonomy presents various elements that contribute to the design of an effective immersive experience and establishes dimensions for each of these elements. Ruscella and Obeid (2021) posit their taxonomy allows designers to sequence an immersive experience, facilitating the objective comparison between experiential design and the strategic modification of those designs to achieve a specific level of immersiveness based on the environment's terminal objective(s). Proposed in 2021, there is no literature testing the taxonomy's application within an actual learning environment. This paper will do just that.

The Coast Guard's IOC, designed around the tenants of the experiential learning theory, relies heavily on scenario-driven training modules and roleplaying. By applying the Taxonomy for Immersive Experience Design, this paper analyzes and compares the effectiveness of the IOC's pre-COVID-19 resident and COVID-19 remote courses. It objectively identifies immersiveness gaps between the two courses that translate to the remote IOC's inability to deliver the authentic and immersive experience necessary to facilitate experiential learning. Further exercising the taxonomy, the paper argues that specific immersive technologies can be strategically implemented within a new virtual IOC to erase the identified immersiveness gap and create an immersive learning environment whose pedagogical benefits surpass that of its resident counterpart.

Media and Fidelity Analysis: Predicting Technological Training Requirements for Unidentified Future Vertical Lift Program

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23140

The lack of training requirements and acquisition of training systems following the design of an operational system often result in training pipeline gaps. To mitigate this challenge and to provide early training systems requirements for the Future Vertical Lift (FVL) platform, a phased media and fidelity analysis (M/FA) was conducted in collaboration with Army stakeholders. This analysis, focused on maintenance training, was an agile systematic approach that provided qualitative data to aid early decision making associated with the procurement of training capabilities. To perform this analysis before FVL requirements were fully solidified, learning objective (LO) data were leveraged from front-end analyses (FEAs) of analogous platforms. These platforms (e.g., CH-53K, CMV-22B) were selected for their overlapping capability and mission scope with the FVL platform.

From the initial set of 100+ LOs, 46 were identified as high priority for FVL maintainers. For each LO, researchers identified necessary sensory attributes (e.g., visual requirements, auditory requirements). Next, a media feasibility determination was conducted to assess the capability of current and emerging technologies to address each LO. Dyads of independent raters assessed and formed a consensus of the ability of each technology to meet requirements. The resulting analysis provided a percentage that represented the degree to which a media option could produce the sensory attributes required to complete a task.

To provide more comprehensive recommendations of training solutions, a subsequent analysis focused on combined media options. Specifically, this analysis indicated complementary media options could be combined to attain better sensory attribute coverage than individual media options. Leveraging this systematic approach during the requirements definition phase of operational platform development, the Army expects to reduce potential training gaps, to improve their return-on-investment, to minimize risk associated with acquiring costly training systems and to prioritize training time on actual aircraft effectively.

On Approach to Reality: The impact of a Simulated Air Traffic Control Environment (SATCE) on Workload and Situational Awareness in Military Aviators

Jonathan Allsop, Ph.D. • Richard Keeling

23166

The use of flight simulators in flying training has become increasingly prevalent due to advances in technology and the benefits that they offer. Advances have led to high levels of fidelity in terms of flight dynamics and systems representation. In relative contrast, little attention has been directed towards the psychological fidelity of simulators, which currently means that core aspects of airmanship (e.g., communication, decision-making, situational awareness) are often not adequately fostered by their use. Simulated Air Traffic Control Environment (SATCE) solutions offer an under-examined method to partially address these shortfalls.

To examine this, a virtual reality based commercial-off-the-shelf flight simulator was coupled with SATCE software. The software injected representative airborne entities into the simulator and provided interactive Air Traffic Control (ATC) via natural language processing. Eighteen participants completed two flight tasks: a normal circuits task, and a general handling task. These tasks were completed in several conditions which were randomised across participants: (1) sterile control conditions, where the SATCE was not enabled, (2) ATC alone enabled, (3) both ATC and entities enabled. Workload, situational awareness, instructor ratings of flight performance, presence, and system voice recognition accuracy were measured.

Results showed that overall workload only increased when both ATC and airborne entities were injected into the simulator. The results from the situational awareness measure, suggest that this was due to the increased attentional demands inherent within this condition. Ratings of presence increased in the ATC alone condition. Voice recognition accuracy was acceptable but could have been improved through more regional-specific amendments to the speech recognition engine. In conclusion, a SATCE offers a promising method to increase the workload and attentional demands placed on aviators in simulators. Further work is required to test SATCE solutions, in an experimentally controlled manner, during actual flying training pipelines.

Data-Driven and Personalized Training as a Service Infrastructure & Techologies

Guido Tillema • Manfred Roza

23184

Modern warfare stresses the importance of maintaining the required proficiency level for todays and future generation air force pilots. These pilots must be able to execute various military missions with rapid deployments, which demands ongoing training. However, today's training is mostly standardized per community and every pilot receives roughly the same training, despite having different learning curves and training needs. As a result, the total training is inefficient, both from a corporate and individual perspective, and does not achieve the best possible operational readiness.

Recent advances in technology, such as artificial intelligence, data science, learning analytics, simulation, x-realities and the internet-of-things, have enabled the implementation of new training strategies, such as performance-based, personalized and adaptive training. These strategies aim to utilize available live and virtual training assets optimally, in order to main the highest possible pilot performance. The digital era allows us to create a service-oriented training ecosystem, which objectively tracks, analyzes and utilizes training data to offer each individual pilot, on-demand, the training most beneficial to their learning curve.

The concept of data-driven training combined with a service-oriented training provision approach is referred to as Training as a Service (TaaS). In this paper, we elaborate on this concept from a technical perspective, including the required architecture for enabling TaaS. The infrastructure consists of several elements: a training element that controls all training-related parts, including the Mission Environment as a Service (MEaaS) and adaptive scenarios; an analysis suite that performs logging and data analysis; a dashboard to control, manipulate and visualize training; and a training orchestrator as the backbone of the infrastructure. We illustrate this with a concept demonstrator developed by Royal NLR, which includes services for training orchestration and scheduling, digital training syllabi, xAPI2 learning lockers, dashboards, learning analytics, cognitive load measurements, and scenario configuration with adaptive Computer Generated Forces (CGF).

A Machine Learning Approach for Identifying At-Risk Students in Learning Record Stores: A Case Study Using USALearning Experience API (xAPI)

Paul Jesukiewicz • Jim Bilitski, Ph.D. • Rob Chadwick • Jonathan Poltrack • John DeCore

23198

The use of artificial intelligence technology in training and education has been increasing over the past few years, with a focus on enhancing the personalized learning experience of students. In order to meet this goal, there is a need for innovative solutions that can adapt to the changing needs of the education sector. One such solution is the Experience API (xAPI), which is a technology standard for tracking and storing learning data.

OPM USALearning designed a project to use artificial intelligence in conjunction with significant amounts of xAPI data tracked to a learning record store (LRS). The goal of this research and development project is to explore the potential of artificial intelligence in improving learning outcomes through the use of xAPI data. The study aims to evaluate the feasibility of using machine learning algorithms to analyze xAPI data and provide personalized learning experiences for students.

This paper reports on the xAPI data collected from different learning environments and how the xAPI is analyzed to identify patterns and trends in student behavior. This information is used to predict learning outcomes of a student, identify at-risk students in need of intervention, and recommend learning content to learners. The study also explores the impact of the modified learning experiences on student engagement, motivation, and overall learning outcomes.

Finally, this paper presents the results of the analysis of a large xAPI dataset of approximately 200 Million data points (xAPI statements). The paper will describe the accuracy of the predictions, at-risk student identification, and describes the validity of recommended content. These features are critical in improving learning outcomes with the use of artificial intelligence in an xAPI-enabled environment.

Mixed Reality Bloodstain Pattern Analysis Simulation Training System

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23203

Bloodstain pattern analysis (BPA) is the study of the size, shape and distribution of bloodstains found at a crime scene. It is a crucial method which can serve to guide the direction of investigation, or validate statement of accounts gathered in the course of investigation.

Conventionally, BPA training requires the creation of mock crime scenes using synthetic liquids splashed onto flipchart papers to recreate bloodstains. Due to the fluid nature of the liquids, there were often inconsistences when creating the different types of bloodstains. Instructors typically need to spend a few hours to create a mock crime scene and the resulting time and manpower invested severely limit the number of training scenarios created and the amount of training that can be carried out.

In order to address these limitations, the team has leveraged on Mixed-Reality (MR) technology to develop a proof-of-concept training system. Through the use of a MR headset, holographic images are projected onto the trainee's field-of-view to create a realistic virtual crime scene with different bloodstains that trainees could interact with, identify and interpret. This allows trainees to build their confidence and familiarise themselves with investigative procedures involving specialized tools such as DSLR cameras, protractors etc. These virtual crime scenes can also be easily created or modified with a library of pre-created layouts and furniture to provide variation in training and assessment.

This paper presents the results of a proof-of-concept trial conducted on the MR BPA training system which investigates the effectiveness and performance of MR technology in enhancing and improving BPA training for officers from the Singapore Police Force. The system is evaluated on four main factors: cybersickness, interactivity/usability, ability to meet training objective and overall system feedback.

Warfighter Readiness: Virtual Training on Demand

Jennifer Quinton • William Rossi • Brian Roder • J. Garrick Sheatzley

23224

Synthetic training has become a key element of the Fleet Response Training Plan. Advancements in Live, Virtual and Constructive (LVC) capabilities have accelerated this trend. Yet still, synthetic training remains a challenging proposition, where warfighters must schedule their participation well in advance and are reliant on the limited resources of training centers to coordinate events, conduct testing, and carefully structure scenarios. Imagine a world more like the one our kids inhabit; a place where military units could connect to game servers that allowed geographically-dispersed units to select training scenarios and participate with other units in tactically relevant vignettes, on-demand with a minimum of overhead. This “anytime, anywhere” concept would allow sailors to facilitate timely mission rehearsal, complete training, receive credit, and glean performance evaluations from after-action review technology designed to enable warfighters to “Get Real, Get Better.”

The Office of Naval Research (ONR) is sponsoring an effort to develop an on-demand wargaming capability to facilitate mission rehearsal and fleet training while underway. Enabling ship training system configuration and readiness, the solution provides automated tests and validation relating to onboard systems and sensors. When complete, this prototype will provide access to an online library of scenarios for dynamic on-demand training, readiness, and re-certification. Research and development on this effort has been conducted by utilizing virtual and bare-metal labs for testing and evaluation. This year, initial tests are being planned with live assets on a pierside ship to evaluate prototype capabilities and, as yet untested, Link 16 integration.

This paper will explore how research has been done to advance the training capability for our future warfighters. It will describe research efforts towards training system readiness and configuration in a virtual lab, architectures and components used while engineering a potential solution, as well as illustrate pierside test outcomes and future growth and sustainment.

Exploring Multimodal Blended Environments for Medical Training and Simulation

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23228

Designing and developing a training system requires a structured approach that encompasses the product lifecycle, from initial analysis of how the system is to be used through system development, verification, fielding, maintenance, and disposal. Much time has been devoted to researching the constraints, benefits, cost, and maintenance of different types of haptics technologies used in medical training devices. In parallel with haptics, a considerably larger body of work has been done in the research and development of Extended Reality (XR) displays including tethered and untethered video and see-through head-mounted displays. To explore the use of haptics to enhance augmented reality medical training for the U.S. Army's Combat Capabilities Development Command Soldier Center, the team created an environment that optimizes the most critical requirements, even at the expense of less critical requirements.

The team evaluated the key requirement parameters and thresholds, as well as the research objective and trade space to develop a Care Under Fire (CUF) training capability that immerses a trainee in defending an enemy attack, moving an injured soldier into concealment, applying a hasty tourniquet and a nasopharyngeal airway (NPA) to the casualty. Post-training evaluations and after-action review (including combat metrics, time to treatment, efficacy of treatment, etc.) can be provided to the trainee, trainer, and third-party observers. These features are enhanced with both first-person and third-person XR displays that function as “windows” into the virtual and physical environment. Communication between commercial, off-the-shelf products and custom, embedded microprocessors allow for a rich range of capabilities within a robust and multimodal training environment. This paper describes the design, development, and trade-offs of an integrated, XR system that makes use of blended environments with virtual and physical interactions, as well as aural and haptic feedback.

Can Synthetic Coaching Using an Immersive Training Device Effectively Train Student Pilots? A Field Study

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23248

Developing and validating innovative solutions to train student pilots as effectively as experienced Instructor Pilots (IP) is a priority for many defense and civilian aviator training programs around the world to increase student throughput, minimize impact of IP shortages, and reduce overall training costs. Innovative training paradigms target the development of low-footprint, immersive simulators that maximize training task coverage and training effectiveness in self-paced environments when aptly paired with digital training solutions that can mimic the behaviors and evaluation heuristics of expert IPs. The current study investigated the utility of training using a Virtual Reality (VR) simulation-based

training device paired with a next-generation synthetic IP providing real-time coaching, feedback, and scoring along with immersive and gamified debrief capabilities aimed to maintain student motivation and engagement. Thirty cadets from a large Indo-Pacific Asian Air Force participated in an hour-long training event practicing basic maneuvers across time. Difficulty was manipulated by alternating time of day. Maneuver performance was assessed automatically against syllabus-based criteria. Cadet workload was assessed via both NASA-TLX and the biometric-based objective Cognitive Workload Classifier (CWC). Pre and post surveys were administered to gauge cadets' confidence and overall training system perceptions. Results show significant training effects across time, along with a decrease in cognitive workload trend. Results are further discussed in terms of cadets' perceptions by experience and performance levels. A key finding shows a strong motivational effect for cadets when using the training system with synthetic coaching and feedback. This study is unique as it was field tested in a germane operational pilot training environment and proves the viability of core aspects of next generation training solutions. Study findings are discussed to address overall strengths and limitations of next-generation pilot training solutions, as well as important consideration for integrating such system within existing and new training courses.

Failure is an Option: Implementing Safe Failure as Learning Strategy

Cami Sims • Thea Albertson • Sharon Rosenthal

23251

Military, civilian, and contractor personnel who handle, store, and transport munitions, explosives, and hazardous materials are subject to a myriad of regulations from the U.S. government, the Department of Defense, and the Army. To keep their jobs, these workers must complete initial and refresher training to maintain certification as prescribed by Federal law. On-demand distance learning exists to meet the wide demand for this certification training. Following 21 certification courses in 2022, over 145,000 learners completed distance learning regulatory courses and were certified to handle, transport, package, secure, and store the world's most dangerous items. The designers and developers of these distance learning certification courses must meet the challenge to apply effective learning strategies that ensure learners can retain and apply the necessary information to keep warfighters and other personnel safe.

In this paper, we explore failure as an effective way to learn using branching scenarios that allow learners to fail safely and repeatedly in a variety of ways. Learners can make a mistake and then correct it. They can fail miserably, resulting in horrific and potentially real outcomes, such as imprisonment, death, or severe harm to others. They can make smart choices where nothing happens—no explosion, no medal or promotion, just going home at the end of their shift. The learners make decisions and "experience" the outcomes. They can always start over and replay the scenario, making different choices.

This paper surveys the existing literature regarding the affect of safe failure on adult learning, discusses how safe failure motivates student receptiveness to learning, presents the key characteristics of safe failing in branching scenarios, and analyzes several years of pass rate data and qualitative data from student surveys from certification courses with high student throughput.

Simulating the Whole Picture with Distributed Mixed LVC

Emilie Reitz • Kevin Seavey • Major Sander Cruiming • Justin Wright

23271

Bold Quest (BQ) is a Joint Staff J6 coalition capability demonstration and assessment event focused on improving joint fires interoperability in a coalition environment. It provides a rich operational environment for assessing new training and simulation technologies, integrated with live command and control systems.

BQ 22 built on the successes of the last several years' work to create interoperable Live, Virtual, and Constructive (LVC) environments, breaking new ground in multi-domain integration between simulated and live forces. The Ft. Stewart Mission Training Complex, 15 ASOS, Colmar Urban Training Center, and DOD experimental vessel, Stiletto, all served as execution locations. The Royal Netherlands Army provided a live instrumentation system (Tactical Engagement Simulation System (TESS)), worn by live units on the ground. TESS allowed virtual and constructive participants to see, react to, and engage live players. The 57 Operations Group provided immersive Advanced Training and Tactics for Combat Kills (iATTACK), which pushed simulated video to a live video downlink. Simulated units exchanged Link 16 messages with live participants, thanks to a J6 JAD software that translated Joint Range Extension Applications Protocol C (JREAP-C) and the Distributed Interactive Simulation (DIS) Link 16 protocols.

As a "capstone event" highlighting these mixed LVC capabilities, 165 ASOS executed a live Precision Strike Team (PST) scenario, using all these integrating capabilities. The live PST JTAC team at Colmar communicated via HF voice and Link 16 with a small C2 cell at the Fort Stewart MTC. That C2 cell communicated via DIS radio with the virtual MQ-9 crew at Hurlburt and the 132 Combat Training Squadron at Des Moines, IA, who played the role of Ground Force Commander (GFC).

This paper describes the lessons learned in conducting mixed LVC events, proposes some long-term implications of distributed mission training, and outlines future ways to improve coalition force interoperability and readiness.

Enabling Point of Injury Care in Live Force-on-Force Exercises

Matthew Hackett, Ph.D. • Mark Mazzeo • Jack Norfleet, Ph.D. • Darin Hughes • Conner Parsey • Brian VanVoorst • Nicholas Walczak • Angela Alban • Edward Stadler

23308

Large-scale military exercises involving force-on-force engagements provide a valuable opportunity to train collectively in realistic battlefield conditions. Unfortunately, battlefield medicine and casualty response have often been excluded due to the burden inherent in their implementation. To date, including medical activities in these training events has required medical manikins

or patient actors, which both require extensive resources and manpower to prepare and utilize. With this manuscript, we describe a capability to enable medical care organic to the exercise, without the need for manikins or patient actors. To achieve this, medical equipment has been instrumented to create surrogate equipment, which collects data during treatment to provide feedback and update patient state. The surrogate equipment is paired with a computer vision system, which uses man-worn cameras to monitor participants and provide measures of task performance. During a training engagement, when a participant is injured by a simulated munition, the trainee uses surrogate equipment to treat the casualty, and is assessed using data from the surrogate equipment as well as the camera system. A user evaluation of the system was conducted during the Synthetic Training Environment Soldier Touch Point 6 for Live Training Systems, at the National Training Center. A total of 19 participants (16 infantry; 3 combat medics) tested the system, providing feedback on the usability, training utility, and current performance of the system. Results were positive for all individual system components and the overall system. Based on initial testing, the use of surrogate equipment combined with a computer-vision enabled camera system represents a feasible and highly useful capability to enable medical care in large-scale military training.

Immersive Space Operations Training in Extended Reality

Daniel Stouch • Rob Hyland • Susan Latiff, Ph.D. • Sean Guarino • Kimberly Brady • Dan Duggan

23321

The United States Space Force (USSF) is envisioned as a digital service to accelerate innovation; however, the training of next-generation space operators largely relies on analog physical models and PowerPoint lectures. Consequently, new operators do not often fully grasp the fundamentals and complexities of the space domain, including threats, hazards, opportunities, and routing maneuvers–leading to longer training times and costly errors.

Fortunately, new training methods involving augmented and virtual reality (AR/VR), collectively extended reality (XR)) have proven effective to educate and train students in many fields and has strong applicability for space education.

This presentation will summarize the emerging state of the art in operational training techniques for space operations using XR techniques, proven to reduce cognitive load, help new operators quickly understand complex scenarios, and make better, more informed decisions. These techniques include immersive, interactive, and collaborative engagement with representative space scenarios, considering maneuver tradeoffs, relative resident space object (RSO) positioning, and mission task deconfliction. 3D Volumetric XR Visualizations provide enhanced spatiotemporal understanding for proximity-based threat and hazard assessments, tactics, techniques, and procedures (TTP) planning, and course of action (COA) evaluations within a configurable virtual environment.

Synchronized AR overlays provide immersive shared access to user-level information and 3D satellite models, while variable timescales enable forward orbital propagation and backward forensic analysis to more completely understand complex orbital scenarios. Dynamic scenario creation tools enable challenging interactive student exercises, instructor-student synchronization accelerates learning through parallel hands-on training, and artificial intelligence (AI)-based skill tracking mechanisms intelligently track student proficiency.

These advanced XR environments, combined effectively with well-formed training curricula and automatic skill tracking will help train professional space operators to better manage complex spacecraft in the dynamic, contested environment beyond the Earth's atmosphere.

Cybersickness Considerations for Curricula Using Virtual Reality Training Systems

Nicholas Adriaanse

23331

There has been minimal work identifying effective durations and cumulative timeframes to enable curriculum development and Virtual Reality (VR) trainer integration ensuring maximum training effectiveness and minimum adverse effects in the long and short term focused on Head Mounted Displays (HMDs).

HMD VR training is reaching higher levels of maturity and incorporation into military schoolhouse training and curriculums. Significant work has been completed analyzing effectiveness of general VR training for teaching specific skills. Research regarding general VR has also identified adverse effects that can occur for a user, such as cybersickness.

This paper presents recommendations for limits of HMD VR incorporation within a military training curriculum from the available literature.

The recommendations draw from analyses mostly focused on improving the development of general VR trainers to mitigate adverse effects. This work has predominantly occurred within Naval Aviation Training where simulators of both Mixed Reality (MR) and VR have been used for some time to great success. Often this cybersickness analysis provides different types of simulators (CAVE Automatic Virtual Environment (CAVE), HMD, etc.) the same treatment meaning that it is difficult to draw specific HMD VR recommendations for curriculum development. The majority of these papers have focused on Naval Aviation Training which has significant motion or head motion due to the nature of the skills and tasks being taught and assessed, that may not be present in other applications.

Due to the limitations in the available literature regarding the integration of HMD VR within military training curriculums a future experiment is proposed to collate the data to enable more effective recommendations.

Simulators Provide Adequate Training – Says Who?

Alexxa Bessey, Ph.D. • Brian Schreiber • Mark Schroeder-Strong • Steven Macut • Wink Bennett, Ph.D.

23333

Simulators have been identified as a vital training resource for the United States military. Compared to live training, simulators provide a cost-effective and safe alternative that can simulate a wide variety of training tasks, procedures, and exercises while minimizing the

use of resources. With advancements in technology, simulators now offer increasingly sophisticated training platforms that can be integrated and augmented with other technology, such as virtual reality and AI. However, as the military moves further into a digital training landscape and live training continues to be replaced by simulator training, it is key for leaders to understand the level of training fidelity simulators provide. For example, poor training fidelity may be indicative of elements of simulator training that fail to adequately provide training experiences compared to high-fidelity training environments, such as live training or more robust simulators. Understanding such deficiencies could inform areas of training that may need to be augmented and/or where to invest in simulator improvements (e.g., upgrades to technology, scenarios, realism, etc.). Further, in addition to understanding poor training fidelity, it is also important to identify areas of adequate or exceptional training fidelity that can continue to be trained with a high degree of confidence. Simply put, understanding both simulator limitations and strengths are critical for developing and sustaining well-trained warfighters. As a result, the following paper outlines a systematic approach to simulator fidelity evaluations that leverages subjective assessments of trainees as well as presents findings from a fidelity evaluation from a sample of United States Air Force (USAF) operators. In addition to findings from the fidelity evaluation, the following paper presents best practices and critical considerations when examining simulator training fidelity that are generalizable across the simulator training community at large.

On Episodic Memory in Experiential Learning via Flightcrew Training Simulations

Nathan Sonnenfeld • Blake Nguyen • Caroline Gomez • Florian Jentsch, Ph.D. • Stephen Fiore, Ph.D.

23396

The training community has relied upon theory and data on memory and learning from the cognitive sciences in its collective practices and research. However, episodic memory and related constructs have been largely overlooked in training literature, particularly in the flightcrew training domain. In this article, we illustrate how the concept of episodic memory may lead to a richer conceptualization of experiential learning implemented through flightcrew simulation training, given growing optimism over the use of extended and virtual reality configurations for unfulfilled niches in the flightcrew training cycle. We describe the concept of episodic memory and its theoretical underpinnings, discuss the role of the episodic memory system in experiential learning, and clarify the unique functions of episodic memory within flight deck operations (across taskwork and teamwork) and flightcrew training (e.g., crew resource management and line operational simulations). Illustrating the practical applications of this work, we describe how the concept of episodic memory can be applied to enhance instructional design features of a virtual reality research testbed for training the external preflight inspection of a B-737 aircraft. We conclude by proposing a set of questions to guide future research on the role of episodic memory in experiential learning through virtual reality simulations in context of flightcrew training.

Immersive Aviation Training Design Driven by the Science of Learning

CDR Adam Jackson • Andrew Clayton, Ph.D.

23401

Due to advances in immersive technologies' realism and affordability, formal military pilot training curriculums continue to incorporate more immersive tools. In most cases, these immersive technologies are used as pre-training for more costly operational flight trainer and flight events. The U.S. Air Force and Navy established Pilot Training Next and Naval Aviation Training Next, respectively, to integrate additional virtual reality and extended reality systems into training curriculums. Initial studies indicate immersive training devices are effective early training tools and enhance live flight performance. While initial results show the potential of immersive training, cognitive psychology studies conclude that massed and blocked practice are largely ineffective means of learning and retention. Analysis of the integration of immersive training devices through learning experience design (LXD) and the science of learning may yield increased efficacy and efficiency in aviation training. This paper explores the application of multiple immersive technologies in three distinct phases of military pilot training: undergraduate, air combat training continuum, and advanced qualifications. This paper first discusses immersive pilot training technologies such as traditional operational flight trainers, 360-degree videos, virtual reality and extended reality flight simulators, airborne augmented reality, and live-virtual-constructive environments in military pilot training. Second, the science of learning will be explored through learning theories, cognitive psychology, and LXD to understand the strategies and development of successful learning. Finally, the paper will present a foundational LXD informed by the science of learning. Each phase of training has unique objectives and skills which influence the desired training tools and methods. The value of immersive technologies in military aviation training cannot be fully realized unless the instructional design incorporates learning experience and the science of learning.

Digitizing Performance and Competencies

Robby Robson, Ph.D. • Shelly Blake-Plock • Benjamin Goldberg, Ph.D. • Kevin Owens • Fritz Ray • Cliff Casey • Gregg Connell

23409

The US Army STE Experiential Learning - Readiness (STEEL-R) project aims to improve training effectiveness in training environments by tracking progress on skill and competency acquisition through multiple developmental stages. Its data strategy involves translating experience API (xAPI) statements that report performance into assertions about competencies and skills in a competency framework, and then using these assertions to estimate the competency state of each soldier and unit. This paper details three critical and broadly applicable processes used to implement this strategy that have not been previously detailed in publications:

The process used to ensure that STEEL-R made the crucial and surprisingly subtle distinction between measuring performance on a task and estimating to what extent learners possess the

competencies and skills required for a task. This paper explains and illustrates this distinction and how the STEEL-R project helped analysts understand and apply it.

The process used to construct competency frameworks from doctrine. STEEL-R uses multi-level frameworks that incorporate principles from learning science and include transferable skills such as leadership and teamwork. This paper details how these frameworks were developed and provides a recipe that others can use for similar purposes.

The process used to translate activity data and performance measures into assertions about competencies. STEEL-R maps performance measures to skills and competencies with "strengths" that reflect the relevance and trustworthiness of the measures. This paper explains how this mapping was defined and implemented.

The processes detailed in this paper have been used by the authors in Army, Navy, Air Force and civilian applications. They are fundamental to any effort to express people's capabilities in digital records that identify their granular competencies and skills. The final section of the paper puts this into the context of the digital transformation that is affecting all aspects of military and civilian life and discusses how these processes are expected to be refined and modified as this transformation progresses.

TUTORIALS

BEST TUTORIAL

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

Roger Smith, Ph.D. • **Peter Smith, Ph.D.**

23T17

There is evidence of games being used for business trade, future prediction, and military strategy for at least 5,000 years. In this tutorial we explore the history of games as tools of military strategy, planning, and training from 3,000BC to the present. We reveal the long evolution of the basic components that are necessary to create a complex game. Concepts that first emerged in India and Asia at the end of the last millennia are still embedded in the games that we create today. Finally we explore how the evolution of serious games shows a trajectory for where games in modelling and simulation are headed, including digital twins, global mobile connectivity, virtual and augmented reality, the rise of generalizable artificial intelligence, automatic content generation, and the metaverse.

The tutorial has four major sections:

(1) Ancient games from 3,000BC to 500AD, with a focus on the essential mechanics and the emergence of game pieces and rules.

(2) Modern game design and early computer implementations from 500AD to 1980AD, in which the mathematics of wargames emerged and offered a format that was amenable to programming in the earliest analog computers of the 1940s through 1980s workstations.

(3) Serious games and the recent embrace of the technology by military leaders at all levels from 1980 to the present. In these last forty years computer-based games have been transformed from crude experiments with the technology to a major workhorse for training in all domains and at all echelons.

(4) Finally, we speculate on the possible future impacts of the metaverse, digital twins, AI, and global mobile connectivity.

BEST TUTORIAL

Behind the Screams: M&S Anatomy and Decomposition of a Contemporary Ride System Attraction

Kevin F. Hulme, Ph.D., CMSP

23T19

Edwin A. Link is widely regarded as the archetype of modern-day flight simulation. In 1929, his LINK trainer was the first commercially developed simulation aviation trainer that has since been designated as an Historic Mechanical Engineering Landmark. Link's key innovation shaped the landscape for what has become a standardized and widely embraced platform for high-fidelity training. Such systems are now commonplace across multiple foundational disciplines at I/ITSEC, including flight, driving, maritime, and others. A related fact is that the Link trainer was patented primarily as a flight trainer - but co-patented as an amusement device. The Link team instantly recognized that their innovative (and engaging) training system could also be implemented for leisure purposes; a prophetic concept, considering the technological state-of-the-art from that period. Now, almost one hundred years later, a powerful cross-synergy continues to

exist between serious-minded M&S training applications and industry-leading simulator-based entertainment experiences – a notion that serves as the overarching impetus for this Tutorial.

In this timely "emerging technologies" presentation, we take a deep dive behind the screams into a recent and revolutionary simulator attraction located at the Walt Disney World Hollywood Studios (Orlando) theme park – Rise of the Resistance. Themed after the Star Wars franchise, Rise of the Resistance is a marquee, technologically groundbreaking multisensory attraction that includes several ride system innovations, motion system components, and industry firsts, including: i) a turntable simulator; ii) trackless planar motion; iii) large-screen immersive 6-DOF platform simulation; and iv) a ride finale that includes a freefall drop segment, never experienced previously on a ride simulator. This Tutorial will describe the end-to-end ride experience (and underlying M&S technologies) and will highlight broader impacts -- dating back to its Link Trainer origins -- associated with the state-of-the-art implementation. The Tutorial concludes with a preview of what is to come in the simulator entertainment sector, based upon both I/ITSEC innovative concepts and current patent technologies made publicly available within recent literature.

BEST TUTORIAL

Putting the When and Where Into Simulations

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

23T68

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

Simulation Conceptual Modeling Theory and Application

Jack Borah

23T12

Simulation Conceptual Modeling 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. It can bound the systems engineering problem and provide valuable artifacts for simulation validation, verification, and accreditation. The emergence of Model Based System Engineering (MBSE) has accentuated the need for well-formed simulation conceptual models. 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. Presenter: Jake Borah is the Co-owner of Borah Enterprises LLC. He is a Senior Operational Research, Modeling and Simulation Analyst supporting the Air Force Operational Test and Evaluation Center, Detachment 2. Jake is a Charter Certified Modeling and Simulation Professional (CMSP). He has frequently supported US and Canadian government sponsored military simulation projects because of his mastery of the M&S technology, and expertise in High Level Architecture federation development. Jake has a BS from the United States Air Force Academy and a Master of Aeronautical Science degree from Embry-Riddle Aeronautical University.

Transportation Systems: A survey of M&S Applications in Mobility, Sustainability, and Logistics

Kevin F. Hulme, Ph.D., CMSP

23T18

Mobility (of people, goods, services) is an urgent bipartisan concern that impacts all humans on this planet. The vitality and well-being of a nation is reliant upon a well-organized transport system and supporting multimodal (e.g., pedestrians, bicycles, cars, trucks, buses, airplanes, trains, trams) infrastructure. For transportation applications ranging from ground vehicles (i.e., both manual and automated), flight vehicles (e.g., conventional aircraft, and automated drones), maritime vessels, and next-generation mechanisms for human mobility, advanced physics-based models

and high-fidelity simulation implementations remain essential for ongoing applications in research, training, and education to advance and evolve our "transportation network of tomorrow."

In this 90-minute Tutorial, an apprentice-level overview of vehicle-based Modeling & Simulation (M&S) will be provided, with a focus on diverse applications in transportation systems. A high-level overview of common modeling methods will be presented with a targeted focus on timely and diverse aspects of human mobility, multimodal transportation, sustainability, diverse vehicle (i.e., land/air/sea) dynamics essentials, as well as the global supply chain and logistics. The NTSA-endorsed Certified Modeling & Simulation Professional (CMSP) curriculum will be closely adhered to, and this Tutorial will serve as a broad introduction to many core/fundamental M&S topics and techniques (e.g., Physics-based, Stochastic, Monte Carlo, Continuous simulation, Discrete-events, Human behavior, and Multi-resolution models) that are featured on the certification exam. Numerous modeling methods will be demonstrated by way of practical and media-driven examples and use cases, all of which will be verbally described (for context), mathematically modeled, and demonstrated by way of media-based simulation.

Note: this Tutorial will constitute the first segment of a "paired event" with a companion Friday PDW: Transportation Systems: An advanced M&S overview for system developers and practitioners.

Finding Fidelity: When You Need It, When It's Too Much, and How to Optimize Simulations for High Training Effect and Low Cost

Thomas Talbot, M.D.

23T20

This tutorial serves as a comprehensive introduction to the concept of fidelity in serious games, simulations, and other forms of interactive training technology. The appropriate use of fidelity has a critical impact on the utility and training effectiveness of a training simulation. When misused, inappropriate fidelity goals result in simulations that are too expensive, too awkward, and too distracting to use that are poorly received by trainees. Smart use of fidelity results in enjoyable, challenging and efficacious training experiences with a measurable impact and great repeat play value.

In this tutorial, the popular impression that fidelity is a primary goal and indicative of quality training is challenged. First, the costs and benefits of fidelity are reviewed and the perils of excessive fidelity are explained with numerous graphical live-play examples. Real-world examples are taken from AI-based Virtual Human Avatars, Virtual Reality Simulations, Virtual Patients and Combat Simulations.

The tutorial then introduces a four step process to matching fidelity goals to learning for a wide range of training applications that cover the full gamut of militarily relevant training. Examples include surgical skills, behavioral interventions, and fire control systems. The tutorial then discusses alternatives to fidelity that improve training experience flow while enhancing user perception of fidelity though exploration of Interaction, Responsiveness and Abstraction. The concept of Bending Fidelity to meet training requirements is also introduced with a live example with Conversational Avatars and another using Tactical Triage. Finally, a comprehensive case study for fidelity is shared and walked through as a capstone activity to creating meaningful experiences and making fidelity judgment calls.

At the end of the tutorial, participants will be presented with sufficient examples to build a solid familiarity with best fidelity practices and how they fit with technology-based training experience. For some, this tutorial will help participants become more astute consumers and evaluators of training simulations. For others, this tutorial will help participants who desire to create new training content as they navigate fidelity judgment calls critical to technology development and effective learning outcomes.

Using OMG DDS for Secure Interoperability Between Multiple Distributed LVC Simulators

Robert Proctor, Jr. • **John Breitenbach**

23T21

This tutorial outlines the use of the Object Management Group's Data Distribution Service (DDS) standard in distributed LVC simulation, with a focus on the security capabilities provided by DDS. DDS provides a comprehensive middleware solution for data distribution, and its security features are crucial for LVC simulation in sensitive environments. The tutorial covers DDS fundamentals, such as configuring DDS for LVC simulation, designing DDS entities and the DDS data model, and integrating DDS with LVC simulations. It also highlights best practices and case studies for DDS implementation. Additionally, the tutorial emphasizes the security features of DDS, such as authentication, access control, data encryption, and data integrity, which are essential for securing data in distributed simulation environments.

Integrating global simulation training systems can be a formidable challenge. Legacy simulators often use different standards. Modern architectures require the use of cloud-based distributed assets. To top it off, security requirements now force integrators to become experts in information assurance. Winning solutions will be ones who create synthetic training environments that can quickly be assembled and reconfigured from ready-made components. How can simulation systems integrators keep pace by limiting integration time to meet these requirements? Attend this tutorial to learn how the Object Management Group's Data Distribution Service (DDS) can ease integration, while also delivering National Security Agency tested security for distributed training systems over any transport.

This tutorial introduces the DDS and DDS Security standards. You will learn how to use the DDS Security standard to securely interoperate with real-world systems that already communicate over DDS, to distributed LVC Simulations.

The tutorial will further describe how to integrate DDS with existing simulation standards, simulation object modes, and data models of any kind, allowing for a large suite of 'qualities of service' to help fine-tune performance and scalability, while also providing robust security for individual entities and topics of simulation data. Next the tutorial will introduce you to the Real-Time WAN Transport that extends DDS capabilities to enable secure, scalable, and high-performance communication over WANs, TDL, RF and public 5G networks. The Real-Time WAN Transport uses UDP as the underlying IP transport-layer protocol to better anticipate and adapt to the challenges of diverse network conditions.

By following this tutorial, readers will gain a comprehensive understanding of how to implement DDS for secure and reliable data distribution in LVC simulations.

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

Thomas Yanoschik, CMSP • Cynthia Forgie, Ph.D. • Cynthia Dunn, CMSP • Stephen Miller • Major Sean Fraser, CMSP

23T22

The Department of the Army has no individual or organization that accredits simulation-based experimentation (SIMEXp). Army Regulations require that the models and simulations (M&S) be accredited- but not any of the other components required to execute a SIMEXp. The purpose of this tutorial is present a framework for SIMEXp accreditation and enable attendees to understand all of the areas which much be accredited for the overall accreditation of a SIMEXp. Accreditation of the M&S will be discussed as it serves as the foundation for an overall accreditation, but there are other equally important components requiring separate accreditations. Attendees will be able to identify the components of tactical and operational scenario which must be validated by current warfighters- and that the person who accredits those aspects must have credible knowledge of the current state of doctrine, military organizations, and operational concepts (friendly and enemy) to be studied. Nothing in the Army's regulatory accreditation of the M&S addresses the physical and computational environment on which the SIMEXp is conducted. For example, if the company commander would only know the happenings of a subordinate platoon's area of operations by what is reported on by voice or texted on a mission command system, then the SIMEXp should be physically structured to reflect those same conditions. Not only must the M&S be accredited, but also the hardware and network on which it is running to ensure processors are robust enough to execute as required, the network transmission speeds are sufficient and no packets are being lost during execution. Finally, attendees will learn how to design and assess the analytical methods used during a SIMEXp to ensure accreditation of the analytical portion of the SIMEXp. The analysis plan, data collection and reduction methodology, and computational methods for analyzing the data must all be documented and accredited in a peer-reviewed final report in order for the overall SIMEXp to be accredited. This tutorial is for those interested in gaining a better understanding of proper SIMEXp design and why more than just the M&S must be accredited. The methodology learned also can be applied to improve simulation-enabled training events and wargames.

Digital Engineering Basic Principles

Frank Salvatore • Darryl Howell • Keith Henry

23T23

The Digital Engineering Basic Principles tutorial will describe foundational terms and concepts associated with Digital Engineering. The tutorial will provide an overview, of the development and application in the Department of Defense (DoD) of:(a) Digital Engineering terminology and concepts used in the Department of Defense (DoD),(b) Digital Engineering technology, architectures and standards and their role in enabling key functions in the DoD, (c) the processes for developing valid models, simulations, “authoritative source of truth” that captures the current state and history of a system’s technical baseline [clarifying words taken from the DoD Digital Engineering Strategy], and the supporting Digital Engineering ecosystem. Attendees will become familiar with Digital Engineering methods emerging in the DoD that support product development activities to include: the development and delivery of training and other areas of direct warfighter support; and DoD acquisition support. This tutorial will identify key policies, procedures, guidance; the need for Verification, Validation and Accreditation (VV&A) in ensuring that models meet the needs of their users; and curation for models to be trusted for use and reuse.

This tutorial will describe the characteristics and associated challenges of Digital Engineering use in: Test and Evaluation, Autonomy, Mission Engineering, DoD Research and Development/ Acquisition and Manufacturing. It will also show the key role Digital Engineering has in developing capabilities that support training, maintenance and DoD operations. The tutorial will also identify accessible DoD Digital Engineering information resources and explain the role of the Office of the Under Secretary of Defense for Research and Engineering (OUSD (R&E)) Digital Engineering and Modeling and Simulation Enterprise, which is the focal point of DoD Digital Engineering, Modeling, and Simulation information, practice, technology, and functional use.

As an outcome of this tutorial, the learner should be able to understand Digital Engineering fundamentals that will help them to get started. The learner will further their understanding of key terms and concepts and how they are being applied. The tutorial will also aid learners in driving digital engineer principles and practices into digital transformation initiatives.

Practical Guide to Learning Engineering

Sae Schatz, Ph.D. • Jim Goodell

23T25

NOTE: This tutorial recieved the 2022 I/ITSEC Best Tutorial award.

The goal of science is to discover the truth about the world as it is. The goal of engineering is to create scalable solutions to problems using science as one tool in that endeavor. Learning engineering is a process and practice that applies the learning sciences, using human-centered engineering design methodologies and data-informed decision-making, to support learners and their development.

Learning engineering brings together professionals from different fields, including the learning sciences, assessment, learning experience design, software engineering, and data science. Learning engineers design learning experiences, but that’s not all they do. They also address the contexts and conditions that lead to great learning. These might include the architecture of physical or virtual learning environments, social structures, and learners’ mindsets as well as more obvious targets such as curriculum design, educational technology, and learning analytics.

This tutorial introduces learning engineering, starting with its definition, purpose, and foundations. Next it covers the core components, including the learning engineering process model

and the field's primary contributing disciplines: learning sciences, human-centered design, engineering, data collection, data analytics, and ethical design. This initial portion of this tutorial will give attendees a solid understanding of the discipline as well as its definitions, utility, and distinctions from related fields. We will use real-world case studies throughout to illustrate concepts.

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

Keeping Up With U.S. Export Controls in 2023

Darren Riley

23T26

The constantly changing dynamic of global politics have resulted in many changes to U.S. export controls in recent years. New U.S. policies towards Russia and China, as well as other countries, are reflected in changes to the Export Administration Regulations (EAR) and the International Traffic in Arms Regulations (ITAR). In addition, there have been changes to the ITAR to reorganize the structure of the regulations resulting in new definitions and updates. This tutorial will provide an understanding of the EAR and ITAR and the impact of the recent changes on the regulations and the export of controlled goods, technologies and services. There will be particular focus on how the regulations apply to the simulation industry, including controls on software, hardware, services and activities at trade shows such as I/ITSEC. Presenters will discuss examples of simulations products and services, and associated licensing strategies, in the current regulatory environment.

Managing Learning Resources Through Use of Metadata Standards

Andy Johnson, Phil Barker

23T27

Improving Human Performance Outcomes depends on the provisioning of learning resources to the individual at the appropriate opportunity. When scaled to an entire workforce, logistical challenges may arise and optimization methods should be deployed. In order to have technology, including artificial intelligence, act as the intermediary for opportunity and optimization, the appropriate amount of data, particularly metadata, about Learning Resources and their corresponding events is required.

When Courseware Based Training (CBT) became popular in the late 1990s metadata was used, usually unsuccessfully, to create repositories of Learning Resources that were intended to be shared across Communities of Practice (COP). Recent efforts in metadata standards, coupled with the advancement of AI, have re-vitalized COPs to attempt to define and enable use cases for learning-based metadata.

This tutorial will describe the learning ecosystem that can be created by metadata and how current standards can be leveraged for success. Specific use cases that can be met through the use of metadata will be described and solutions presented. These use cases include, but are not limited to search, discovery, application within learning, optimization of both learners and the resources themselves, and lifecycle management of learning resources. The landscape of available metadata standards, and particularly how they can be combined, will be described in great detail and attendees will have the opportunity to model such solutions in accordance with these standards. These standards are centered around the LRMI vocabulary from the Learning Resource Metadata Innovation (LRMI) workgroup of Dublin Core Metadata Initiative and IEEE Learning Metadata Terms (P2881) efforts but will include other metadata standards and are applicable beyond. The benefits of using Resource Description Framework (RDF) best practices will be described and realized in the tutorial and accompanying learner-created metadata graph.

P2881 is an effort created by those familiar with legacy metadata standards used in the Shareable Content Object Reference Model (SCORM) and how those failed in application. P2881 attempts to define a small core model applicable to all types of Learning Resources that is applicable to solving particular use cases and leaving the further definition of types, such as "courses", to respective COPs. A core component of P2881 is the distinction between Learning Resources and Learning Events. Learning Resources are defined by LRMI and have been thoroughly defined and accepted the standards community. Learning Events are instantiations or opportunities of Learning Resources that are bound by time, materials, and human capital.

A Process for Distributed LVC Integration and Execution

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

23T28

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

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

An instantiation of DSEEP was developed based on the authors' integration and execution of many distributed LVC events. This implementation has nine steps, divided into 27 activities. This

process adds two additional steps to the process. One of the steps adds a tabletop wargaming step to work through the requirements. The second additional step develops a digital twin of the target system. A detailed set of processes, templates, and guidance on how to perform the selected activities is provided. The process covers the integration of simulations and tactical systems to meet the objectives of the LVC event.

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

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

Modernize Your Training by Migrating Legacy SCORM Content to cmi5

Brian Miller

23T29

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

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

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

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

This tutorial will help attendees better understand how to utilize cmi5 and the freely available course templates from cmi5 CATAPULT to migrate, create, and test their courseware to ensure they conform to the cmi5 specification. After an introduction to cmi5, where it fits into the Total Learning Architecture (TLA), and why eLearning standards are a necessary component of modern learning ecosystems, this tutorial will walk attendees through converting legacy SCORM content to cmi5 using the sample course templates and describe the importance of testing in ADL's cmi5 Content Test Suite.

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

Creating a Data Strategy and Learning Analytics

Jonathan Poltrack • Rob Chadwick

23T30

Understanding data strategy, analytics, and key performance indicators is critical to the successful application of learning analytics in an organization. Many organizations develop and deploy expensive training solutions but do not include a comprehensive data strategy and analytics plan. As a result organizations may not understand how their learning content is used, when students require intervention, and when and how to update content so that learning is more effective and efficient.

This tutorial provides a comprehensive overview of designing and implementing an effective data strategy for learning analytics. Participants will gain knowledge and skills necessary to document algorithms, metrics, and visualization requirements to create effective analytics. The tutorial will include the development of a short data strategy to address a sample use case. Attendees will perform an evaluation of the key performance indicators by determining how to evaluate data visualizations. Participants will leave the tutorial with a solid understanding of the main functions of learning analytics, the components of a data strategy, and how to apply these concepts in practice.

This tutorial is for data scientists, xAPI professionals, learning content developers, and instructional designers who have a requirement for or interest in learning analytics and visualizations.

Illuminating the ATO Process – Lessons Learned the Hard Way

Victoria Claypoole, Ph.D. • George Moats • Powell Crider

23T31

Authorization to Operate (ATO) - a mythical unicorn for some, a holy grail to most, and a regular occurrence for those who recognize the difference between vulnerable and exploitable. ATO at its core is simply an official declaration made by an authorizing official (AO) to allow a system to operate within their boundary. To achieve ATO, the security posture of the system must be rigorously documented, evaluated and approved. Earning ATO often takes years and generally millions of dollars. ATO is the critical milestone for all systems that seek to become operational in the DoD. In

accordance with policy, whenever a new software application or system is being considered for DoD use, the security posture is evaluated from inception through fielding to ensure that ATO can be achieved. Unfortunately, stakeholders often ignore security leading to insurmountable blockers, specifically for those that are transitioning from the commercial sector to DoD use.

It is critical for companies to include security within their early design and architecture. Adversarial threats in a firm's code and tech stack will likely result in ATO being denied and require the firm to rework the entire architecture to remove and replace the offending code - leading to additional development, delays, and money wasted. In this vein, the lack of ATO inclusion can perpetuate the ‘Valley of Death' for small business and pose a significant roadblock in transitioning from research and development to operations and sustainment. This tutorial aims to encourage all attendees to become familiar with the authorization process before development of a new system / technology begins.

This presentation will discuss: i) what an ATO is, different types of ATOs, and associated security constructs, ii) the roles and responsibilities of everyone that plays a part in the ATO process - from government to industry, iii) where to start with an ATO and all the steps a company needs to take to achieve it, iv) tips and tricks for shortening the time and effort required to achieve ATO through a Certificate to Field or Cyber Impact Analysis, v) lessons learned from a small business who recently achieved ATO, vi) ATO reciprocity and how to make your ATO work across the DoD, and vii) how to maintain your ATO. By the end of this tutorial, attendees will be able to describe the steps needed to achieve an ATO.

Introduction to Defense Modeling and Simulation

John Daly • James Coolahan, Ph.D.

23T32

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

Evolution of RF Signal Visualization from Spectrum Analyzers to Augmented Reality

Jad Meouchy • Suzanne Borders

23T33

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

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

How to Build at War Time Resilient Online Learning System

Geir Isaksen • Maksym Tyschenko • Serhii Salkutsan • Piotr Gawliczek

23T34

The war in Ukraine shows us the importance of maintaining the ability to educate and train (new) military personnel in time of war. The Armed Forces of Ukraine (UA) have a robust online system that is a vital part of their educational system. For more than 10 years the Norwegian Defence University College (NDUC) and NATO Defence Education Enhancement Program (DEEP) have worked together with the National Defence University of Ukraine named after Ivan Chernyakhovskyi (NDUU) to establish a resilient UA online learning system.

The efficiency of the UKR ADL system was proven during annual evaluation visits (2020 and 2021) conducted online during the COVID lockdown. Of importance is to stress the UKR input as far as the development of the NATO DEEP Strategy for Distance Learning Support is concerned. So, it means that this system has already been proven under pandemic conditions and now in the time of war.

From September 2013 to February 2023, total 145 ADL-focused NATO DEEP events were conducted, involving 1800+ Ukrainian participants. Such formats were introduced as postgraduate studies “”e-Teacher and e-Instructor within a new learning environment caused by COVID-19””, e-Instructor Certification Program, and dedicated projects: Computer Adaptive Language Testing - CALT, translation of the NATO and Norwegian ADL

courses into Ukrainian, involving SMEs from UKR (i.e. Cyber Defence Awareness - CDA), and translation of the book ""Modernizing Learning"" into Ukrainian.

This tutorial will tell the story on how NDUC, NATO DEEP and NDUU for several years have planned and executed the project of establishing this vital capability for Ukraine. Furthermore, the tutorial will cover the strategy applied to reach these goals, courses and training needed to get a resilient online learning system and the technical solution and security aspects. How the online learning system is used in war to enhance military capability and how Ukraine has cooperated with international partners will be outlined during the presentation. The online system will also be presented and at the end NDUC, NATO DEEP and NDUC will cover lessons learned and recommendations from a long-time cooperation process, also introducing innovative solutions, based on XR/ AI technologies.

Making the Case: Building Strong M&S Verification and Validation Evidence

Simone Youngblood • Katherine Ruben
23T35

The processes of Verification, Validation, and Accreditation are foundational elements that underlie assessments of M&S credibility. Verification and Validation (V&V) activities serve to build an evidentiary chain of information upon which M&S Users can assess the viability of an M&S for a particular application. Information derived from the V&V processes is used to shape the understanding of how and where an M&S should be used and under what the constraints.

While V&V is founded on basic software engineering principles, implementation is often constrained by resources, whether these resources be time, money, personnel, or information. This tutorial will address the key steps that can be taken to build strong V&V evidence while accounting for resource impacts. The tutorial will incorporate lessons learned derived from multiple VV&A applications.

Topics to be covered by this tutorial will include:

- Requirements traceability that provides the link between requirements and V&V testing
- Identifying verification test strategies (e.g., leveraging information, supplemental test activities)
- Building and applying validation referent data (what the simulation results will be compared to)
- Defining the simulation measures and metrics to use as the basis of comparison (the aspects of the results that will be compared to the referent)
- Selecting validation methods to apply when performing the results/referent comparison
- Documentation templates and tools that provide efficiency of process to the V&V effort

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

Introduction to HLA 4

Bjorn Moller • Katherine Morse, Ph.D., CMSP
23T36

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 in general and the new HLA 4 version in particular. It describes the requirements for interoperability, flexibility, composability and reuse and how HLA meets them. It also describes the new features of the most recent version: HLA 4, such as security, scalability and cloud deployment. Finally, it provides some recent experiences of the use of HLA in NATO M&S groups as well as an overview of recent evolution of Federation Object Models for military platform simulation, space simulation, cyber simulation and air traffic control simulation. This tutorial is intended for all audiences; however, some familiarity with basic principles of distributed computing is recommended.

Machine Learning: An Introduction for Humans

Randolph Jones, Ph.D., CMSP
23T37

The modern digital world imposes key constraints and opportunities on how best to sustain a global force. On the one hand, the scale of available digital data and the pace of technological change demand solutions that can adapt quickly to massive amounts of data and rapid development of new capabilities. On the other hand, the increased digitization of information provides opportunities to exploit these enormous amounts of data, if only adequate technology can be employed to exploit the data. One of the best emerging candidates for exploiting this data is the rapidly advancing field of machine learning. The ability to automatically extract lessons and patterns from large amounts of data has the potential to be an essential force multiplier for improving effectiveness and rapid adaptation of training, simulation, and education.

The field of Machine Learning (ML) began in the 1950s, and it became a major, widespread research area in the 1980s. Over the past 10-20 years, innovations in computer hardware, computer languages, computer memory, and new algorithms have kicked off a rapid escalation in the capabilities of ML systems. As a result, the common refrain from stakeholders is “I want my system to learn!” But what does it really mean for a system be able to learn? When is it a good idea and when is it not? What kinds of things are computers good at learning, and where are there still weaknesses? How does this all work, really?

This tutorial abstracts away from the mathematical and computational details to offer a high-level understanding of “How ML Works”, as well as its capabilities, strengths, and weaknesses, The tutorial presents the broad categories of learning that current ML approaches address, together with examples that provide an intuitive feel for how each approach is able to work, without delving into the specifics of the complicated math that provides much of the “magic”. The tutorial also investigates the “art” behind the science, introducing the work an ML practitioner needs to add to apply these powerful algorithms successfully to new problems.

The tutorial finishes by summarizing some of the types of human learning that are still on the ML frontier, waiting to be understood and conquered, as well as an overview of methods to decide which parts of your problem might be best suited to NON-learning algorithms.

Live, Virtual and Constructive (LVC) Interoperability 101

Kurt Lessmann • Damon Curry

23T38

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

Building Trusted AI: An Introduction to Human-AI Trust

Michael van Lent • Jeremiah Folsom-Kovarik • Dylan Schmorrow • Denise Nicholson, CMSP • Brian Stensrud, Ph.D.

23T39

Artificial Intelligence (AI) is transforming how humans do everything from getting to work to diagnosing illnesses to creating art. In all these applications, AI occupies a gray area between a tool (like a calculator) and a partner (like a colleague). AI is more than a tool because AI systems have goals, dynamically plan actions to achieve those goals, and adapt to the situation based on experience. However, humans can't build the relationships with an AI system that they do with a trusted colleague. AI's undeniable value in high-stakes, life-or-death decisions coupled with AI's status as more than a tool but not yet a partner raises fascinating questions about how and how much humans should trust AI systems. These questions are especially critical for the training and simulation community, given its leading role in the deployment of AI.

This tutorial will review the science of trust across both the social and physical sciences and describe the three key aspects of AI trust: trustworthy, trustable, and trusted. Prominent theories and models of trust will be discussed and consideration of those applied throughout the human-AI lifecycle will be explored. Approaches to assessing AI trustworthiness will be explained including their relation to the DoD's existing VV&A process. The technical requirements the AI system must meet to be capable of gaining a human's trust will be detailed, including explainability, transparency, natural interaction and building common ground. Subjective and objective (behavioral and physiological) trust measurement approaches will be explained. All of this will surmount to a final discussion of human-AI trust calibration and the future of human-AI trust centered on the realm of the possible for standards (e.g. TRL equivalent for trust of a system, trustworthiness index for AI operational fielding decision). The tutorial addresses researchers, developers, and evaluators who create or use artificial intelligence. No technical knowledge is required.

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

Robert Murray

23T41

As any gamer will tell you, it is compelling to connect simulations and play with other actual human participants, whether in the next room or on the next continent. Distributed Interactive Simulation (DIS) is an enabling technology that connects military training and engineering simulations for that purpose.

Successful research in the 1980s led to an international effort to standardize a network protocol for linking military training and engineering simulations. DIS was the result, using the IEEE standards process to create a technically sound and widely accepted protocol. IEEE 1278TM-1995 and additions in 1998 were the first full DIS standards that contained the protocol and rules for real-time simulation interoperability of military land, sea, and air platforms, weapon interactions, radar, radio, IFF, laser designators, underwater acoustics, logistics, simulation management functions, and more.

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

This tutorial explains how DIS achieves real-time high-fidelity interoperability over best-effort networks. The basic concept and some of the technical details will be introduced to give students a foundation for starting and expanding the implementation and use DIS in their simulations. The standards process, history, and future directions of DIS are also presented. Emphasis on DIS Version 8 will review current developments and upcoming improvements to the DIS standard.

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

Adam Kohl • Eliot Winer, Ph.D.

23T45

According to Defense Secretary Lloyd Austin, the Department of Defense is making artificial intelligence (AI) research a "top priority" by investing approximately $1.5 billion in AI projects over the next five years at the Defense Advanced Research Project Agency (DARPA). Machine learning (ML), a subfield of AI, has quickly become critical in fields such as engineering, learning association, and medicine due to its ability to produce adaptable models that can perform a variety of complex tasks. Recently, ML has been leveraged to produce enormous benefits in extended reality (XR) enabled environments including education and training. However, understanding the vast field of ML and its utilization in training

systems can be extremely challenging. Miscomprehension can lead to poor management and development activities that result in more costly and underwhelming training solutions. Grasping ML fundamentals and emerging concepts, and its application to XR will empower managers to make appropriate strategic and costing decisions and allow designers, developers, and engineers to successfully implement effective training systems.

This tutorial will expand on last year's overview of ML technologies to include emerging concepts, methods, software, and hardware, while detailing how these can be integrated into XR education and training environments. The presentation will highlight examples demonstrating ML's use in design, testing, and optimizing XR training systems with a variety of simulation engines and hardware devices. Additionally, this tutorial will evaluate each example's efficacy of incorporating the technology to aide in warfighter training by improving efficiency, reducing costs and training time, and sustainability.

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

Driving Proficiency through Mobile, Immersive, Hands-on eXtended Reality (XR) Training

JoAnn Archer • Claire Hughes • Eric Martin • Joe Ruisi

23T47

Training is often consumed in the classroom or remotely as a one size fits all structure with limited opportunity and/or costly simulations to practice hands-on skills in contextualized situations. Providing training to sustain a global force in a digital world must be mobile and offer the ability to "act out" or practice critical skills to instill muscle memory, embody actions, and formulate critical thinking. By utilizing an integrated approach of augmented, virtual, and mixed reality technologies, eXtended Reality (XR) training can provide a contextualized virtual environment (which links the learning of foundational skills to practical scenarios and operational stressors) with augmented overlays and real-world objects (to scaffold instruction via multimodal cues tied to the real-world) creating a fully immersive and highly engaging training environment. When XR training applications are embodied and accessible an opportunity exists to provide psychomotor practice in a highly engaging environment leading to significant proficiency gains in both primary and refresher training. Providing trainees immersive, hands-on XR training anytime, anywhere using applications downloaded to a mobile device enables consumption to be readily available and learner centered offering an action-oriented option very different from traditional classroom and remote training.

It is crucial when developing XR training solutions to evaluate the utility of the novel contextually based design elements and embodied interactions afforded by XR. This challenge is further complicated when implementing XR training using handheld mobile devices. XR does not have a proven, common mental map for the way users expect to interact with XR content on a mobile device especially when spatial movement is required. It is critical to build systems and UI/UX interaction capabilities that optimize users expected interaction paradigm with future facing technology.

This Emerging and Innovative Concepts tutorial will dive into the key elements of a mobile immersive training platform that leverages andragogically-based activities and formative assessments to infer trainee proficiency by providing insights into: key drivers of immersive, accessible training in XR; potential implementation barriers and technical challenges to embodied training in XR when using mobile devices; value-added case studies with end-user feedback; and user-centered guidelines for designing, developing and implementing mobile XR training systems. By the end of this tutorial, attendees will be able to implement effective techniques for developing and implementing immersive, accessible mobile XR training applications based on case studies in the military medical, transportation, logistics, and maintenance domains.

Generative AI Applied to Rapid Development of Simulation and Modeling Assets

Jad Meouchy • Suzanne Borders

23T52

Simulation environments, virtual and otherwise, are often bottlenecked by the content creation process of art design, graphical modeling, and data integration. This asset development pipeline is slow and costly, requiring specialized labor that can complicate the logistics or expose the operational security of a training objective. However, the emerging field of generative AI allows one individual to direct a single computer to build libraries of relevant, usable materials through simple voice or text prompts. Once the tools have fully matured, the net increase in productivity and speed will likely be measured in multiple orders of magnitude.

This tutorial will review and critically analyze modern sim production workflows against the next-generation approach of directed AI, and explore the numerous possible trajectories of this highly disruptive new technology. The audience will gain a deep understanding of the current generative AI methodologies with a particular emphasis on applied utility rather than theoretical potential. Together, we will walk through common simulation challenges and dissect the corresponding AI prompts that generate passable solutions within mere seconds. The audience will learn how to begin testing these new tools and be given recommendations on how to use them effectively and securely.

Implementation Strategies for Creating a Sustainable xAPI Data Strategy

Florian Tolk • Elizabeth Bradley

23T54

The xAPI specification is due to be approved as a standard under the Institute of Electrical and Electronics Engineers (IEEE) Learning Technology Standards Committee (LTSC) in 2023. Department of Defense (DoD) Instruction 1322.26 recommends the Experience Application Programming Interface (xAPI) data specification as the primary method for encoding and exchanging interoperable learner performance data across the DoD enterprise. xAPI statements are a form of JavaScript Object Notation (JSON), a common data format used across industry and government.

While xAPI can encode data about formal learning experiences, it also can support informal learning, such as on-the-job training, self-directed learning in work environments, or even student engagement in virtual classrooms. But because xAPI enables such broad data interoperability it presents a complex challenge in the design phase and in implementation. The creation of an xAPI data strategy helps establish the business rules for how xAPI is used across organizations to collect and interpret learner data from different digital learning systems.

This tutorial will focus on the tools, technologies, and processes for implementing xAPI to meet organization-wide objectives. While some attention will necessarily be placed on the instrumentation of learning activities with xAPI, the primary focus of this tutorial is lessons-learned on how to implement best practices so that learner data is Visible, Accessible, Understandable, Linked, Trustworthy, Interoperable, and Secure (VAULTIS).

Each organization within the DoD has its own unique challenges when implementing xAPI. Attendees of this tutorial will work through different use-cases to illustrate the value of an xAPI data strategy. Attendees will walk away with actionable knowledge about how to use xAPI profiles to continuously improve organizational insights into the wide range of digital learning systems.

Getting UX – Understanding UX and How to Acquire It

Amanda Hawkins • Vel Preston • Dolores Kuchina-Musina

23T67

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

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

>> Generate requirements for products that are based on end user input

>> Iteratively design and test experiences with end users

>> Focus solutions on solving the right problem and avoid over-engineering solutions that are solving unnecessary problems

This tutorial will explain the UX design process and explain how it reduces overall risk to delivery. Participants will also learn how incorporating UX design principles ensures the output of modeling and simulation is aligned to the intended application. We will also discuss how to acquire UX capabilities to support your next project.

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

Introduction to Design of Experiments

Kelly Avery • Keyla Pagan-Rivera • John Haman • Rebecca Medlin

23T69

Understanding the experimental design process is fundamental to conducting efficient and effective tests and model and simulation experiments. This tutorial aims to provide a comprehensive understanding of the test design process, with practical examples and demonstrations. Our goal is to provide you with the skills to create a good test design and effectively communicate statistical results in reports.

The tutorial begins with an introduction that explores the test design framework and explains the concept and purpose of experimental design. We then delve into the various aspects of planning, design selection and evaluation, and the analysis of an experimental design. Within the planning phase, we cover the essential elements such as identifying test objectives, response variables, and factor selection. We then provide an overview of different types of experimental designs and their purpose. In evaluating a test design, we discuss important metrics like power and confidence that are used to ensure adequate data collection and assess the quality of the design. Lastly, we cover some best practices for analysis and reporting, such as avoiding data “roll-ups”, incorporating interval estimates, and utilizing high-level graphical summaries to effectively communicate the results.

By the end of the tutorial, you will have gained a better understanding of the test design process and will be equipped with valuable insights and techniques for creating and analyzing experimental designs.

PROFESSIONAL DEVELOPMENT WORKSHOPS

Fundamentals of Artificial Intelligence for Simulation-based Training

Robert Sottilare, Ph.D. • Brice Colby, Ph.D. • Randolph Jones, Ph.D., CMSP

23W2

This half-day professional development workshop is designed to provide participants with a comprehensive overview of the fundamentals of artificial intelligence (AI) in the context of simulation-based training. Through a combination of lectures, hands-on activities, and case studies, participants will gain a deeper understanding of the key concepts and technologies in this field, and will learn how to apply these methods to improve the quality and effectiveness of simulation-based training.

Using DDS for Distributed Training Simulators

Andre Odermatt • John Breitenbach

23W4

This workshop outlines the use of the Object Management Group® (OMG®) Data Distribution Service (DDSTM) standard in distributed Live, Virtual, & Constructive (LVC) simulation, with a focus on the security capabilities provided by DDS. DDS provides a comprehensive middleware solution for data distribution, and its security features are crucial for LVC simulation in sensitive environments. The tutorial covers DDS fundamentals, such as configuring DDS for LVC simulation, designing DDS entities and the DDS data model, and integrating DDS with LVC simulations. It also highlights best practices and case studies for DDS implementation. Additionally, the tutorial emphasizes the security features of DDS, such as authentication, access control, data encryption, and data integrity, which are essential for securing data in distributed simulation environments. Integrating global simulation training systems can be a formidable challenge. Legacy simulators often use different standards. Modern architectures require the use of cloud-based distributed assets. To top it off, security requirements now force integrators to become experts in information assurance. Winning solutions will be the ones that create synthetic training environments that can quickly be assembled and reconfigured from ready-made components. How can simulation systems integrators keep pace by limiting integration time to meet these requirements? Attend this tutorial to learn how DDS can ease integration, while also delivering National Security Agency (NSA)-tested security for distributed training systems over any transport.

From the Last of Us to the First of Us: Rebuilding after a Zombie Crisis

Tamara Griffith, Ph.D. • Patricia Bockelman, Ph.D. • Joan Johnston, Ph.D. • Sarah Matthews, Ph.D. • Lisa Townsend • Grant Johnston

23W7

WE SURVIVED THE APOCALYPSE!!!... Now what?

This workshop takes participants through a post-crisis timeline in which the decisions and actions taken today will impact scenarios tomorrow. This is an interdisciplinary exploration of how a civilized society might thrive, or fail to survive, after a potential infrastructure collapse. While the scenario uses metaphor for engagement (the zombies), it is inspired by a combination of real-world events involving public health, national security, and public resources (e.g. transportation, supply chain, cyber/information). Nested in this fictional storyline, participants will establish needed resources, skills, and new social norms and by doing so, these participants will create the world that next year's I/ITSEC participants inherit. Participant groups will represent various perspectives as they try to transition from "survival" to recovery and (hopefully) "thriving". While the storyline is fantastic, the scenarios pose challenges that call for real decision-making strategies, negotiation skills, and short-/long-term planning; the scenarios demand the same types of skills as actual recovery requires. This is intended to be a multi-year exploration with the results of the previous year feeding a paper for the next year, and a workshop that starts where the previous year's workshop ends pursuing a stable and sustainable future. The immediate and longitudinal data from this format will provide insights into tacit knowledge involved in complex team problem-solving. Come for the fun; learn from the insights! You may have outlived the zombies, but can you thrive with whatever unfolds next? At the end of the workshop participants should understand the 4 dimensions of teamwork and how team self-correction during an after action review can improve teamwork.

Serious Game Design Workshop

Vance Souders • Radhakishan R. Shetty

23W10

During this workshop, participants will be introduced to key concepts, steps, and processes involved in designing a game for learning. Through hands-on activities and working together in groups, participants will work through the initial phases of the design process. Participants will identify a topic, audience, training requirements and learning objectives, creating an effective story, determining instructional and gaming strategies, designing key game mechanics, and choosing the appropriate delivery technology. Presenters will facilitate the groups and give examples from past experiences and provide examples from the Serious Game Showcase and Challenge.

Demystifying Learning Engineering and Immersive Design: The Workshop

Jeanine DeFalco, Ph.D. • Marina Halter • Emily Ouellette

23W12

Designing virtual reality (VR) training simulations may not seem difficult at a glance, but even the simplest interactions can be complex in the VR space. In this workshop, participants will experience what it's like to go through the design process, create a prototype, and iterate until a final product is produced. Participants will review the basics of learning engineering, immersive design, and constructivist learning theory, and come to understand how these disciplines are leveraged to construct training simulations. Participants will identify important traits, skills, and capabilities that combine into up-skilling an immersive learning engineer. Participants will be introduced to how learning engineering combines fundamentals of instructional designers and learning experience designers (LXDs) while simultaneously engaging in collaborative design work as part of a cross-functional design team. Best practices for engineering dynamic immersive learning experiences will be discussed.

Cognitive Load Assessment During Training in Immersive Environments

Andrew Beall, Ph.D. • Matthias Pusch • Bryce Armstrong • Todd Hartwig

23W13

Join us for a hands-on workshop where we will explore the measurement of cognitive load and the application of immersive training simulators. Researchers and developers will delve into projection-based simulation room technology, a robust alternative to head-mounted displays, offering enhanced realism and interaction capabilities vital for standardized training processes. With the Tactical Combat Casualty Care (TCCC) protocol serving

as our case study, participants will learn to integrate cognitive load measurements into simulation scenarios. Attendees will gain practical experience with an immersive projection system and learn how to capture 360 degree photographic scenes for evoking contextual cues. An experimental session will allow some participants to have their cognitive load measured under various conditions, and then all participants will be able to conduct real-time data analysis guidance using open-source tools. This workshop is designed to equip attendees with an understanding of cognitive load measurement, immersive training technology, and data analysis for effective training simulator development.

Disrupt, Design, Deploy: A Human-Centered approach to Learning and Development

Sydney Heimbrock, Ph.D. • Ryan Twedell • Cydney Miller

23W14

The discipline of Learning Engineering has emerged as mission critical for enabling evidence-based designs for improved learning outcomes. Harvard University's Huntington Lambert defines Learning Engineers as understanding the "who" an organization is teaching, and the "what" the learning must deliver, in order to design the "how" of learning experiences. Because humans are at the center of this challenge, the methods and tools of human centered design are critical for effective learning design, development and delivery. This workshop will give participants an immersive experience in Human Centered Design (HCD) for Learning and Development. The workshop will kick off with a brief presentation framing the value, history and outcomes of HCD as it relates to the future of learning. Participants will learn and practice HCD by applying the framework, methods and tools to a real government learning experience use case. Participants will learn the four key phases of the HCD process:

- Discover

- Reframe

- Prototype, Test, Iterate

- Implement, measure and continuously improve

For each phase of the HCD process, facilitators will present the principles, methods and tools, then support participant small groups to apply them in the room to design the future of learning in their organizations. Participants will then explore how to apply HCD to digital learning ecosystems through automated qualitative data collection and analysis. Participants will leave the workshop educated, inspired and equipped to apply a human centered approach to their learning design, delivery and evaluation strategies.

Certified Modeling and Simulation Professional 3.0

Ivar Oswalt, Ph.D., CMSP

23W15

The Certified Modeling and Simulation Profession (CMSP) certification program has been reinvented and reintroduced to the M&S community as CMSP 3.0. The certification's application process has been streamlined, the examination updated, and an approach to ensure readily available reference material developed, amongst many other additional improvements. This proposal is to conduct a CMSP 3.0 Professional Development Workshop. This four-hour session will describe the requirements needed to achieve this valuable certification. It will cover the application and examination processes including education, work experience, and reference requirements for the Apprentice, Practitioner, and Master Levels; application processes; how the exam is administered and scored; and the role of continuing education in certificate renewal. It will also provide timely insights into preparing for and achieving this certification including, new in 2023, review of sample questions from each of the three certification levels. It will discuss fundamental M&S topics covered in the exams and will also include several relevant simulation videos. Finally, the workshop will conclude with two enjoyable interactive game-show style exercises to summarize the material covered, a rapid-fire question and answer game, as well as a round-table discussion regarding ongoing efforts to ensure this certification's future success. The proposed Professional Development Workshop would be provided by Ivar Oswalt - a Senior M&S Expert that is CMSP Certified, that has been an integral part of its reinvention, and that has previously led CMSP Professional Development Workshops.