ADAPTIVE SIMULATION-BASED TRAINING FOR A COMPLEX WORLD

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ABSTRACT
The U.S. Army must operate in a highly complex world and dynamic operational environment (OE). In order to maintain pace with a rapidly evolving OE, the Army must distribute training and education to its soldiers and leaders at the point of need. The Linguistic Geometry Real-time Adversarial Intelligence & Decision-making (LG-RAID) simulation supports this goal and is being developed for the Army to train leaders to rapidly develop tactically sound plans. The LG-RAID simulation is a planning tool for Army leaders that semi-automatically generates enemy estimates in a semi-immersive setting. The tool accurately anticipates the enemy's actions, reactions and counter-actions, resulting in the development of a qualitatively better tactical plan. In this paper, we discuss the development and design of the simulation to meet the Army's objective of training leaders to meet the challenges of a complex OE. We also discourse on development and design challenges faced and the future employment of the simulation to meet the Army's objective.

Keywords: simulation, training, predictive analysis, course of action

1. INTRODUCTION

The United States Army operates in a highly complex and dynamic operational environment that requires leadership that is both agile and capable of critical analysis (Graves & Stanley, 2013). As the Army exits a prolonged period of counterinsurgency warfare, more emphasis is being placed on training for major combat operations (MCO) as its focus broadens (Odierno, 2012). In fact, recent Army doctrinal changes stress the importance of lethality, even referring to this capability as the foundation for land operations (Benson, 2012). The Army's challenging transition back to MCO training is occurring in the midst of a resource-constrained environment and subsequent manpower drawdown (Snider, 2012).

In light of this environment, new approaches to training as well as new technology are required in order for the Army to most effectively and efficiently prepare its leaders for an uncertain world. Simulation-based training (SBT) is an evolving domain and represents one of many potential new approaches to solving this dilemma. Recent literature highlights effective changing approaches to employing SBT in both the medical profession (Hamstra, Brydges, Hatala, Zendejas, & Cook, 2014) (Arora, et al., 2014) as well as military (Stevens & Eifert, 2014) (Sotomayor, Mazzeo, M., Hill, & Hackett, 2013) (Blow, 2012).

The U.S. Army continues to discover novel ways to use SBT (Lele, 2013) since it has been empirically demonstrated to successfully provide transfer of training from the simulated environment to the live environment (Harrington, 2011; Blow, 2012; Seymour, et al., 2002; Hays, Jacobs, Carolyn, & Eduardo, 1992; Salas, Rosen, Held, & Weissmuller, 2009). Game-based training, defined as the employment of interactive software for training that is generally characterized by its low overhead and cost (Bergeron, 2006) is a new variant of SBT that offers tremendous promise. In this paper, we discourse on a new game-based trainer that the U.S. Army is developing in order to meet the training needs of Soldiers operating in a complex environment.

Software tools based on advanced Artificial Intelligence represent a potential breakthrough that may facilitate the Army's objective of effectively and efficiently preparing its leaders for a complex OE. In this paper, we discuss both the development and design of the Linguistic Geometry Real-time Adversarial Intelligence & Decision-making (LG-RAID) simulation tool to meet the Army's goal of training leaders to operate successfully in a complex OE. We also discourse on development and design challenges faced and the future employment of the simulation to meet the Army's objective.

2. BACKGROUND

2.1. LG-RAID

LG-RAID is a new Army Research Laboratory (ARL) development effort and technology that may assist the Army in its pursuit to train leaders to meet the challenges of a complex OE. Linguistic Geometry (LG) is a game theory that has demonstrated an ability to solve large-scale problems in near real-time (Stilman B.

, 2014) (Stilman, Yakhnis, & Umanskiy, 2010). It is particularly useful in solving strategy-like problems, such as mission planning, by representing them as a class of opposing games, the so-called Abstract Board Games (ABG). LG provides highly efficient decomposition of the game state space by projecting it on the Abstract Board, generating strategies, and elevating them back to the state space (Stilman B. , 2014) (Stilman, Yakhnis, & Umanskiy, 2007) (Stilman B. , 2000).

As the name implies, the LG-RAID tool makes use of the LG algorithms to solve a class of real-world ABGs. In this case, the ABG is a tactical planning mission being conducted by an Army leader. Thus, LG-RAID is a light-weight simulation that employs novel game theory to generate intelligent, predictive and tactically-correct courses of action (COAs) for mission planning exercises (Stilman & Yakhnis, 2003).

2.2. Technology Enabled Capability Demonstration 7

Senior U.S. Army leadership identified and prioritized the Army's top ten science and technology challenges in 2011 in response to a rapidly changing operational environment (Buschmann & Pellicano, 2014). In order to demonstrate that these challenges were being adequately addressed and progress subsequently measured, the U.S. Army Science and Technology (S&T) Advisory Group created the Technology Enabled Capability Demonstration (TECD) concept. For each of the top ten challenges, a TECD was established to demonstrate and rapidly deliver high-impact, innovative technological solutions to complex problem sets. One of the top ten challenges designated by Army leadership was the improvement of training techniques and technologies for small unit and leader training. In order to address this particular designated challenge, the TECD 7 effort was created.

The purpose of TECD 7 was to conduct research and develop training technology and methodologies to achieve a more effective training capability to enhance small unit, squad, and leader performance across the full range of military operations (Martinez, 2012). One of the emerging technologies selected to participate in the TECD 7 effort was the LG-RAID simulation due to its potential high-payoff in improving leader training. In the following section we discuss the development and design of the simulation to meet the Army's objective of training leaders as a part of the TECD 7 effort. We also discourse on development and design challenges encountered and the future employment of the simulation to meet the Army's objective

3. METHOD

3.1. Capability Development and Design

The overarching objective of the TECD 7 effort was to provide “an immersive, full-spectrum, training experience for Small Units at home station and/or while deployed that approaches the complexity and realism of fixed-site combat training centers but requires a minimum of infrastructure and pre-event preparation” (Freeman, 2011). We identified the following design goals in order to achieve this objective:

- Ease of deployment and access
- Streamlined user interface
- Game-like interactive use
- Simplified terrain import

3.1.1. Ease of Deployment and Access

In order to allow trainees ubiquitous access to the LG-RAID simulation, a cloud-based service was chosen as the primary deployment approach. The tool was designed to be installed on a server (or multiple servers) and then accessed by end-users over the network using a common browser requiring no configuration for the end-users. Standard installation package and custom configuration tool (LGConfigTool) wizards were employed to deploy and configure the entire software stack on any Windows-based operating system. The LG-RAID installation was fully self-contained and included any required components, such as web server, databases, and 3rd party modules. This provided both simplified and more secure deployment by removing the need for and risk of installing and misconfiguring other software packages. All client-server communications are performed using well defined and documented REST API (Representational State Transfer Application Programming Interface) over HTTPS (Hypertext Transfer Protocol Secure) using JavaScript Object Notation (JSON) and Extensible Markup Language (XML). This approach provided serveral benefits: security due to encrypted communications, compatibility with government and corporate firewalls, and ease of integration. This communication can take place over the local area network (LAN), virtual private network (VPN), or over the Internet, NIPRNET, or SIPRNET (Figure 1).

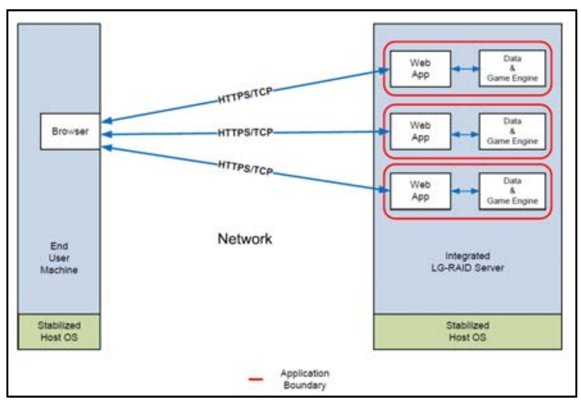

Figure 1: LG-RAID Network Communication

If desired, standalone installation can be accomplished by installing the server components on the end-user's Windows computer. As described above, the installation and configuration process is similar in difficulty to any commercial off-the-shelf (COTS) software and can be performed by the end-user. All the

LG-RAID processes are executed as Windows Services, running in the background, and do not interfere with normal computer operations. Server and local deployment support allow us to address needs of various training organizations. Cloud-based option provides ubiquitous access without need for infrastructure maintenance; however, it requires a stable Internet connection that may not always be available in training facilities. Alternatively, local server installation provides a small and secure cloud instance within individual classrooms without external network connectivity. Finally, the standalone LG-RAID option, loaded on each student's laptop, provides a fully disconnected option.
The other benefit of local or Internet-based cloud deployment is an opportunity for collaboration between multiple users of the same server. The Requests and Updates Manager (RUM) component of LG-RAID implements support for multiple simultaneous users. Each user can save and load scenario files, perform Simulation Based Training execution, as well as collaborate with other users by exchanging files or participating in *Joint Editing* sessions for concurrent editing on the same scenario. As a classroom training tool, these functionalities can also be leveraged for instructor-student communications such as exchange of assignments.

3.1.2. Streamlined User Interface

For consistent experience for both standalone and cloud-based employment, the end-users are able to access the tool using the web app either locally from the same machine where the server components are installed or from any COTS laptop or desktop computer, with any modern operating system using a common Internet browser such as Chrome, Firefox, or Internet Explorer. Using the web browser provides additional benefit of familiarity to the users. It was assumed that students would have previous exposure to the profusion of consumer web applications, such as maps, email, and social networks. Thus we leveraged this experience and reduced training requirements by providing a user interface that employed familiar elements (Figure 2).

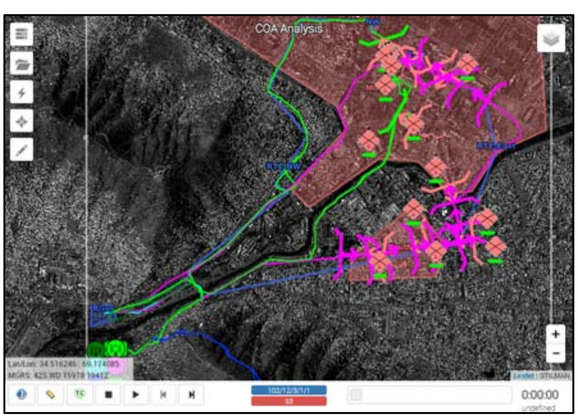

Figure 2: Streamlined Interface

To achieve this, the LG-RAID interface was built using the same open source technologies that drive some of the popular commercial websites, including HTML5, CSS, Bootstrap, AngularJS and Leaflet map engine. As a result, the look and the feel of the UI match user's expectations from other familiar applications and leads to intuitive use (with little training required). For example, the LG-RAID user interface (UI) employs the same control to move a map with a mouse as all common Internet mapping applications. Additionally, visual on-screen queues are used to guide the user through the functionality, e.g., drawing a polygon on the map (Figure 3).

Figure 3: Polygon Depiction in LG-RAID UI

It is important to consider that the target user of this software is a military student. Therefore, the UI should leverage both common web application elements and military concepts. This includes such features as use of the Military Grid Reference System (MGRS) in the bottom left corner and doctrinal Army terminology in mission specifications.

3.1.3. Game-Like Interactive Use

LG-RAID had been previously employed in a COA analysis role, where the entire mission is automatically evaluated using the Artificial Intelligence (AI) engine based on the initial BLUFOR mission plan and OPFOR information provided by the user. This method is applicable for training for providing comparison between alternative COAs. This comparison includes qualitative analysis based on visual animated playback of the mission as well as quantitative evaluation based on numerical mission statistics. Both types of analyses could be employed by the students and the instructor. To further enhance this functionality, mission statistics have been expanded to include expected casualties and fuel and ammunition expenditure for both friendly and enemy forces (Figure 4).

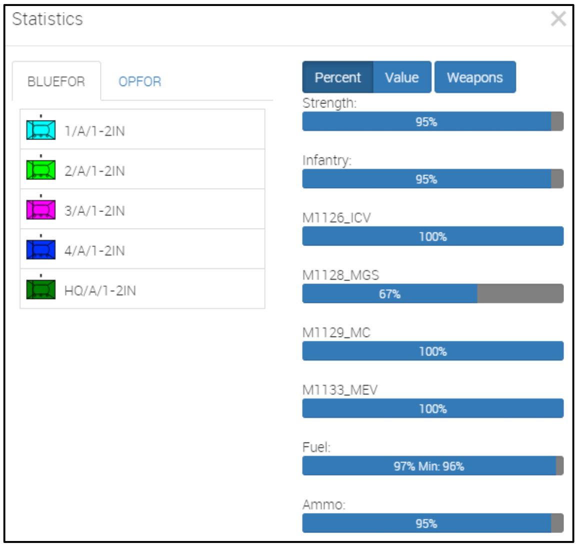

Figure 4: Expanded Mission Statistics

Additionally, more immersive simulation based training was achieved by introducing a new game-like interactive mode. The student begins by entering the BLUFOR mission plan. However, the enemy information, prepared by the instructor, is hidden from view. During mission execution, the student can watch the plan unfolding as friendly forces move across the map, enemy forces are discovered, and engagements take place. At any point, the user can pause the simulation and alter their mission plan by changing taskings for any of their units. As the simulation is resumed, the LG-RAID engine automatically adjusts the enemy's actions in reaction to this change to provide the student with a challenging enemy. In addition to dynamic control of the OPFOR, the engine removes the need to micromanage the BLUFOR. For example, the Company Commander in training can simply assign tasks to the platoons, and LG-RAID will fill in intelligent actions for the subordinate units, removing the need for human players to act as platoon leaders or squad leaders. This approach was used to provide ubiquitous access so that students can perform training exercises on their own without any pre-event preparation or additional support personnel, which was a key requirement of the TECD 7 program.

3.1.4. Simplified Terrain Import

A common challenge for simulation based training has been availability and quality of terrain data. Often times, simulation terrain databases have to be augmented with additional information such as stair cases, doors and window locations, as well as photorealistic textures for 3D visualization. In order to keep this simulation light weight, only Digital Terrain Elevation Data (DTED) and shapefile feature data are required for LG-RAID. Additional information such as windows, doors and floors is inferred. Such *source* data is typically easier to procure, however, it typically requires some processing to correct any errors, inconsistencies, or non-standard formats. The Terrain Data Manager (TDM) was added to the LG-RAID toolset to simplify this process. TDM (Figure 5) can be used to produce *geospecific* regions, i.e., representing a real-world area, or *geotypical* regions, i.e., non-specific representations of terrain typical for a given area. The latter is especially useful for training as it challenges the student with operations on several, different versions of the same terrain.

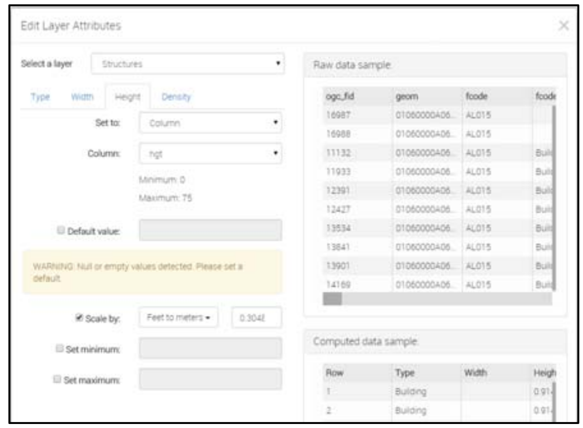

Figure 5: Terrain Data Manager (TDM)

Any set of shapefiles and DTED files can be uploaded through the TDM web app. The user can then use a wizard interface to classify the data, choose key data fields, such as heights, and perform conversions between measurement units. In addition to such bulk format corrections, the user can also view terrain features overlaid on top of the satellite pictures and manually correct the shape or parameters of any specific feature, such as a road or a building (Figure 6).

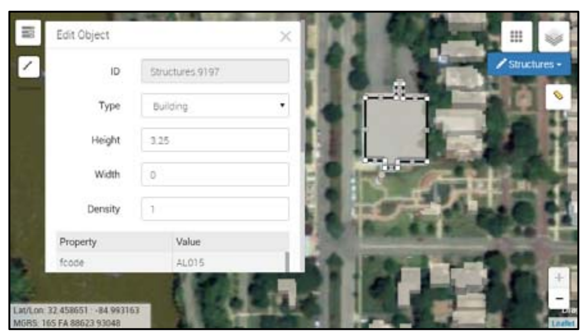

Figure 6: TDM Wizard Interface

Once the data has been classified and corrected, the Deploy Region Wizard is used to automatically process the terrain area into a format required for the LG-RAID simulation engine. This unattended cycle can take several hours, and, once done, the user can perform Simulation Based Training on this new area.

In addition to producing underlying data required for the simulation, TDM can also be used by instructors to prepare raster images that will serve as a map background for the student. These can be produced from any common formats, e.g., GeoTIFF (Georeferenced Tagged Image Format) or RPF (Raster

Product Format). The instructor can choose to provide only the maps appropriate for the exercise, while removing access to other. For instance, the student could be allowed to use topographic maps but not high resolution satellite imagery. This capability was added to support doctrinal training such as the student's ability to perform tactical analysis using specific geographic products.

3.2. Challenges

One of the challenges with producing a training product for the Army is adhering to strict Security Technical Implementation Guides (STIGs) required to obtain a Certificate of Networthiness (CoN). These guidelines were used by the development team to provide security of the overall system. To follow these guidelines requires additional work for the final product release for installation on Army computers. Additionally, as any web-based application, this system must be resilient to network latencies and outages. Our team chose to address this challenge by reducing the need for a constant server connection. The web-based GUI is responsible for all scenario creation and visualization of results without relying on server-side processing (with the exception of actual simulation computations). This was achieved by leveraging the power of modern web browser technologies mentioned previously. For universal accessibility, the web GUI has to support common browsers including Chrome, Firefox, and Internet Explorer. However, due to the novelty of some of the HTML5 standards, additional testing and workarounds are needed to address numerous inconsistencies across these platforms. This can be even more difficult in light of the additional security configurations that affect Internet Explorer operation on some of the government laptops that employ the Army Gold Master Windows Operating System.

Another common challenge has been to ensure that the user interface remains easy and intuitive to use. We have kept the usability at the forefront of development through rapid prototyping, usability testing, and feedback from target user groups, retired military subject matter experts (SMEs), instructors, and students from military learning institutions. These efforts endured through the entire lifecycle of this project to ensure the final version remained easy to use as the capabilities of the software and the complexity of the UI grew.

The training provided by the system must be consistent with the US Army doctrine to be effective. Capturing the doctrinal taxonomy, specific equipment, tactics, techniques and procedures presented a significant challenge. These military concepts must be translated into the specific LG models in order to support analysis by the LG-RAID engine. Close collaboration between the military SMEs and the software development team was necessary to continuously refine and improve fidelity.

Terrain data availability is a common challenge to any simulation system. While TDM can now be used to help address some of the terrain-related problems, producing new or correcting very poor terrain data remains manually intensive. We adopted the strategy of requesting areas of interest from target user groups as early as possible in order to mitigate the time required to procure and prepare the data. Additionally, we proactively prepared terrain data, as requested by TECD 7 stakeholders, in order to provide them with common training locales such as the National Training Center (NTC).

3.3. Future Employment of the Simulation

Preliminary demonstrations have already been conducted with the Maneuver Captains Career Course (MCCC) and Cavalry Leaders Course (CLC) at the Maneuver Center of Excellence (MCoE), Ft Benning in order to gather direct user feedback on current functionality and identify key directions for future development. The next step in this project is to employ the LG-RAID software for Simulation Based Training within the scope of a particular Army schoolhouse course, such as MCCC and CLC, for more direct assessment of applicability and required enhancements. Such testing is currently slated to begin during the summer of 2015 using two Company level training scenarios at MCCC.

Once the project's Certificate of Networthiness has been received, all three methods of deploying the software can be supported. Cloud-based deployment on the Army Games for Training servers would provide easy access. However, some classrooms prefer installation on individual laptops. Based on previous feedback, yet another deployment option is the use of a laptop-based server with a WiFi hotspot to support instructors that travel to numerous training locations, such as National Guard Training Centers. Most of these courses last only a few weeks, and an easy, low overhead system with little-to-no training requirement is essential.

While standalone, low overhead, SBT is the primary goal, integration with other simulations and mission command systems may be of interest to training courses. For example, using LG-RAID to stimulate Mission Command systems could allow the students to train using the same exact software systems that they will later use in the field.

A key area for future improvement is breadth and depth of the military scenario modeling provided by the tool. Past focus of LG-RAID has been on maneuver force-on-force Company level operations. However, the key simulation capability can be extended to both lower (i.e., Platoon) and higher (i.e., Battalion and Brigade) echelons. Larger scale operations in particular, would require a significantly larger set of units and mission types. Supported mission types can be expanded to include more detailed representation of reconnaissance, engineering, and logistics operations. This development will proceed in tight cooperation with the SMEs from specific Army courses to ensure a high degree of relevance to particular learning objectives. Additional features can also be introduced to the User Interface to support these learning objectives, such as Line of Sight, Surface Danger Zones, and others. Interactive and collaborative features of the tool can also be expanded to allow for teams of students to play against each other in a real-time multiplayer team environment, including support for instructor interventions.

There are many other directions for the future employment of LG-based simulation tools. One of them is simulation based acquisition. For this purpose, the LG technology permits modeling and evaluation of new conceptual military hardware in terms of its functionalities before actually building it. Using LG tools, the analysts will create a gaming environment populated with the Blue forces armed with the new conceptual hardware as well as with appropriate existing weapons and equipment. This environment will also contain the intelligent enemy with appropriate weaponry and, if desired, with conceptual counters to the new Blue weapons. Within such a LG gaming environment, the analyst will run various what-ifs with the LG tools providing the simulated combatants with strategies and tactics solving their goals with minimal resources spent. If the new hardware functionality has hidden flaws, the simulated enemy guided by the LG strategies would be able to exploit them providing the hardware evaluators with hands-on proofs of failure. Contrariwise, if the new hardware functionality has spectacular advantages, the Blue forces guided by the LG strategies would be able to convincingly demonstrate how these advantages could be translated into victory for the Blue forces. This not only helps the evaluators to assess the hardware's advantages, it will help to convince the funding agencies to fund the prototype construction. In similar fashion, several alternative functionalities could be compared using the ultimate criteria – how well the conceptual weapons and/or equipment will do against an intelligent adversary fully simulated by the LG tools. Experimentation within the LG simulated environment may provide an inexpensive alternative to the live exercises typically conducted for the same purpose.

4. CONCLUSION

In this paper, we described how simulation is enabling the U.S. Army to adapt to a complex and dynamic operational environment (OE). The TECD 7 effort was the Army's collective training response to a rapidly changing operational environment. The LG-RAID simulation was chosen as a TECD 7 participant due to its potential high-payoff capability, in alignment with the TECD 7's charter to develop training technology and methodologies to achieve a more effective training capability to enhance both small unit as well as Army leader performance across the full range of military operations.

We discoursed on the development and design of new LG-RAID capabilities that will support the achievement of the TECD 7 mission. Ease of deployment, a more streamlined interface, higher interactivity and rapid terrain importation are a few of the critical capabilities currently being developed with this goal in mind. We also covered challenges encountered during our design and development cycles as well as future methods of the simulation's employment.

The LG-RAID simulation will provide the Army with a low-overhead capability to train its leaders on tactical planning in response to a changing OE. The ability to maintain pace with a complex and dynamic OE, through the use of adaptive simulation, is a strategic goal for the Army's leadership and training communities of interest. The LG-RAID simulation, through its design, development and testing cycles, is on pace to meet this goal.

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Dr. Boris Stilman is the Chairman & CEO at STILMAN Advanced Strategies (STILMAN) and Professor of Computer Science at the University of Colorado Denver. Dr. Stilman leads STILMAN since its foundation in 1999. All the software applications including LG-RAID developed at STILMAN are based on Linguistic Geometry, a new type of game theory in Artificial Intelligence, which has been originated and further developed by Dr. Stilman since 1972. He has published over 200 research papers.