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Using Web Technologies to Streamline Preparation for Simulation-Driven Training Exercises

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Preparing for Distributed Training Exercises

Preparing for a large, distributed training exercise requires a significant amount of effort. Part of this preparation can involve installing software for each trainee station and copying appropriate configuration files, scenarios, and terrain data. Setup is usually an ongoing, recurring activity, due to inevitable changes and upgrades. Invariably, as new files are copied, mistakes are made and errors can result due to mismatched systems. If these errors are not discovered quickly, it can lead to time-consuming delays during the exercise, which results in wasted time and effort as trainees are forced to wait until the problem is corrected and the exercise restarted.

An Approach to Streamline the Process

The use of web technologies can help alleviate this setup effort by restricting the necessary configuration to a server and then having the training application and associated data streamed to each trainee as-needed. By leveraging web services, training systems can make use of common software already installed on each system (browsers) that use well-known technologies. This approach improves scalability, enabling any number of trainees to connect to the exercise without the need to pre-install any software or data on their systems.

When people hear *web* or *browsers*, they immediately think *the Internet*. However, the use of web technologies does not mean that the exercise *must* use the Internet. Instead, it describes a set of technologies that enable computers to access and share resources and data across a network. That network infrastructure could be a Local Area Network (LAN) or a Wide Area Network (WAN), including the Internet, but also a number of available commercial or military WANs. For example, this could be the LAN that links multiple classrooms at a training facility. It could be a private WAN that links multiple training facilities. It could also be the Internet, enabling trainees to access training from their home, with or without extra layers of security to protect the data.

Web technologies can help streamline the process, enabling[1]:

- IT staff to more easily provide automatic and centralized updates of software, terrain, and other content.
- Trainees to participate in exercises, either on private networks or over the Internet.
- Instructors to look over trainee's shoulders and view the exercise using tablet-based stations.
- Multiple role players to use lightweight interfaces to command semi-automated forces applications running in a server room.
- Controllers or observers to use their smart phone to view or manage the Common Operating Picture.

- Exercises to easily scale to support large numbers of participants across various remote locations.
- Exercise managers to save money using virtualization, cloud-based simulation, and the thin-client paradigm.

Web Technologies

HTML5, the latest revision of the standards for structuring and presenting web-based information, provides a number of enhancements to the elements and APIs supporting complex web applications[2]. These improvements now provide an even better framework to support web-based simulation applications. For example, HTML5 provides native support for multimedia such as video, audio, and dynamic imagery. WebGL supports 3D graphics in a browser, without the need for plug-ins, but still taking advantage of local hardware acceleration. WebSockets enable flexible, real-time, bi-directional networking. JavaScript Object Notation (JSON) is a lightweight data-interchange format that is easy for humans to read and write and is easy for machines to parse and generate. Finally, there are a large number of available JavaScript libraries, many of them open source, which can be leveraged.

Rather than review all the available HTML5 features that are useful to provide better support for simulations, this paper will focus on two specific web technologies that are critical to enable simulation-based training systems to operate effectively. These include the WebLVC protocol and a number of existing web mapping specifications standardized by the Open Geospatial Consortium (OGC).

WebLVC

Distributed simulations have typically used several interoperability standards to share real-time data. These include the Distributed Interactive Simulation (DIS) protocol and the High Level Architecture (HLA). However, neither the DIS Protocol Data Unit (PDU) and UDP network transport nor the run-time infrastructure (RTI) programming library approach of HLA seamlessly fit within current web-based frameworks.

To bridge this gap, the WebLVC protocol was developed to enable web and mobile applications to interoperate within traditional Modeling and Simulation (M&S) federations. It is an emerging Simulation Interoperability Standards Organization (SISO) standard that helps link applications developed using typical web-based frameworks and simulation interoperability standards like DIS and HLA[3].

The WebLVC protocol specifies a standard way of encoding object update, interaction, and administrative messages as JSON objects, which are passed between client and server, typically using WebSockets. WebLVC can represent arbitrary types of objects and interactions. However, WebLVC also includes a Standard Object Model definition based on the semantics of DIS, HLA's Real-time Platform Reference (RPR) Federation Object Model (FOM), and the SISO Enumerations for Simulation Interoperability[4]. The advantages of WebLVC include:

- The JavaScript approach seamlessly incorporates into standard web app frameworks. JSON is the natural way of encoding structured data intended to be used by web-based applications, because a JSON object is a string-literal representation of a JavaScript object.

The JavaScript language has built-in serialize and parse functions which generate JSON strings from JavaScript objects, and vice versa, without the need for data marshaling or conversion. JSON is both human readable (text) and machine readable.

- The built-in Standard Object Model makes interoperability with existing DIS and HLA RPR-based simulations straightforward.
- The flexibility to support arbitrary object models, including simple extensions to existing messages, provides the ability to support additional FOMs or customer PDUs, if necessary. This can be done by defining new types of objects, attributes, interactions, and parameters.
- The client-server nature of WebLVC connections supports efficient interest management, enabling clients to register subscriptions and filters with a server.

OGC Web Mapping Specifications

Given the nature of military training exercises, supporting simulations generally use or display geospatial data in some form. This could be as 2D maps, as a 3D visualization of the environment, or as the source data used for analyzing the terrain for vehicle movement, simulating sensors, communications, or other military systems, or enabling semi-automated forces behaviors. Most simulations rely on local copies of this terrain data. As the areas of interest for each exercise expand and high-fidelity geospatial data becomes more readily available, the requirements to store this data has grown exponentially. Although disk drive capacity also continues to become larger and less expensive, the process of copying and re-copying data is time-consuming and prone to errors.

The optimal solution is to store a single reference dataset and for each application to access that data when needed. OGC has published a number of web mapping specifications to enable transmission of geospatial data across a networked environment[5] that can be leveraged to support this approach. These standards can be used to provide the foundation to deliver the imagery, elevation, feature data, and 3D models to support real-time applications, both for visualization and simulation. The data can be provided on-demand, avoiding the need to copy large terrain databases to each trainee PC, and can be controlled in a central location helping manage possible terrain correlation and update issues.

Many of us routinely use Google Earth, Google Maps, or the many other web mapping applications to view locations, calculate driving directions, or discover other information about a particular location. Using these available standards rather than *reinventing the wheel*, we can use the same approaches to support real-time simulations.

Some relevant standards include the set of specifications used to request and stream georeferenced raster tiles across the network. These include the OGC Web Map Tile Service (WMTS) standard, as well as its precursor, the Open Source Geospatial Foundation (OSGeo) Tile Map Service (TMS) specification. Both standards define the mechanisms for how clients request map tiles and how terrain servers describe available data. Data is provided at fixed scales, each containing different zoom levels. The top-level can provide a single tile covering the entire area and then be subsequently subdivided into more detailed tiles. These standards support both raster imagery and elevation data. The data can be used to render 2D maps or to generate the terrain meshes and textures used for 3D rendering.

Feature data can also be streamed across the network. The OGC Web Feature Service (WFS) standard can be used to request and access geographic feature data. The feature data could be rendered as symbolized points, lines, and areas. For 3D, procedural rendering techniques can be used to render the geographic objects using the provided geometry and attributes. For example:

- A building area is extruded, using attributes like height, type, etc., textured with geo-typical exteriors, or replaced with specific models or textures based on the name or other identifying attributes.
- Point trees are replaced with 3D models representing attribute data including type and height.
- Land cover vegetation area features are replaced with specific models distributed according to attributes like vegetation type, cover percentage, average size, etc.

Frequently, features are not displayed but rather used to support terrain reasoning. This could include road or river networks used for navigation, land cover used for mobility calculations or cover and concealment, weather conditions over specific areas for effects on visibility, movement, and sensors, or any other analysis that can lead to more believable simulated dynamics or behaviors.

There are several approaches for network-based 3D models. Feature data could just be mapped to local libraries of generic models (e.g. trees, bushes, geo-typical textures). There are also several ongoing efforts to standardize web distribution of 3D models. Some have used COLLAborative Design Activity (COLLADA) models, originally intended as an interchange file format. OGC has several 3D scene initiatives including CityGML, the Indexed 3D Scene Layers (I3S), and other specifications under the 3D Portrayal Service (3DPS) standard.

VT MAK has been actively using these OGC standards for several years to support 2D and 3D visualization as part of its commercial-off-the-shelf (COTS) products VR-Vantage (visualization) and VR-Forces (simulation). Both products can use traditional local terrain database formats like OpenFlight, Common DataBase (CDB), or other terrain formats. However, they can also directly make use of terrain data streamed from a server, like VT MAK's VR-theWorld server, which implements the OGC streaming terrain formats. Both products use a number of techniques to efficiently use the streamed terrain to enable real-time rendering and simulation.

Figure 1: VR-Vantage screenshots showing streamed elevation, imagery, and procedural features with 3D models for entities simulated by VR-Forces

Use Cases

Advantages of Streaming Terrain

For the last two years, VT MAK has participated in the Interservice/Industry Training, Simulation and Education Conference (I/ITSEC) Operation Blended Warrior (OBW). OBW is a planned multi-year exercise to demonstrate and explore the potential for Live, Virtual, and Constructive (LVC) capabilities to maximize training, education, and testing for the defense and security sectors. In 2016, the Terrain Working Group decided to focus on identifying common source data from which Image Generator (IG) vendors could produce their final run-time products. The primary area of interest (AOI) was Southern CA, mostly focused around Camp Pendleton. A number of publicly-available US Geological Survey (USGS) datasets were identified including 1m and 1ft imagery and 10m elevation, which would serve as the basis for the terrain skin. As discussions proceeded to refine the one or two specific Military Operations on Urban Terrain (MOUT) sites that would be used to demonstrate the ground operations, it was discovered that USGS had also released 1m digital elevation models (DEMs) and source LIDAR data for much of the AOI including all of Camp Pendleton. The difference between the 10m and 1m elevation is significant, especially for ground combat operations.

Figure 2: A comparison of rendered 10m elevation (left) to 1m elevation (right), draped with the same 1ft imagery as displayed in VR-Vantage.

Despite being very late in the exercise preparation process, the decision was made to use the 1m elevation data for the Camp Pendleton area. Participating system integrators had to reprocess their terrains in order to use the new data. In many cases, the integrator could not or chose not to use that level of fidelity, resulting in correlation issues in the final exercise. However, because VT MAK used the streaming terrain process, the new data was uploaded to the VR-theWorld server, where it was composited with the existing 10m elevation data for the AOI, and 30m global data along with 10m and 90m bathymetry data. VR-Forces simulations were rerun and the terrain visualized with VR-Vantage with little effort. Figure 3 and Figure 4 shows the results of the data streamed from VR-theWorld.

Figure 3: VR-Vantage screenshot showing 1m elevation, 1ft imagery, and procedural vegetation in Camp Pendleton.

Figure 4: Another screenshot showing elevation, imagery, procedural vegetation, and ESRI-produced MOUT site.

Supporting Thin-client Tools for Legacy Simulation Environments

Under a project sponsored by the US Army's Joint Coalition Training Research (JCTR), Dynamic Animation Systems (DAS) and VT MAK demonstrated that web-based apps could be used alongside the existing monitoring and control tools within the Army's LVC Integrating Architecture (LVC-IA) Program of Record[6]. Current LVC architectures are composed of a number of different applications, which often have their own methods for exercise planning, scenario creation, exercise monitoring and control, and after action review (AAR). The focus of the effort was to evaluate approaches to provide a common interface to LVC systems that could be used across a number of disparate systems.

For the first phase, the initial use case was to integrate the One Semi-Automated Forces (OneSAF) Computer Generated Forces (CGF) simulation, which has broad usage throughout the US Army, with web-based 2D and 3D viewers. To support the test environment, VR-theWorld was used to host and provide the terrain data and VT MAK's WebLVC Server was used to serve as the gateway between DIS, HLA, and WebLVC and to host the WebLVC-based apps. DAS and VT MAK worked cooperatively to identify appropriate OneSAF scenarios and terrain data. The scenarios were evaluated on the basis of the breadth of different entity types, their interactions, and number of entities. The scenarios provided a number of tested cases to evaluate the 2D and 3D viewers.

For the 2D viewer app, VT MAK expanded its existing Commander app (Figure 5). The Commander app is an AngularJS, OpenLayers, and VR-Link.js JavaScript application than can visualize 2D streamed map data and WebLVC-based entities and aggregates as MILSTD 2525C symbology. The Commander app provides the following capabilities:

- Select and display details about entities
- Display shooter-to-target lines
- Pan and zoom the map
- Toggle on or off map layers
- Select and track entities
- Display unit status as MILSTD 2525C Operational Condition (health) symbology
- Display speed leader lines showing relative speed and direction
- Display mouse position coordinates, displayed scale, and overview map

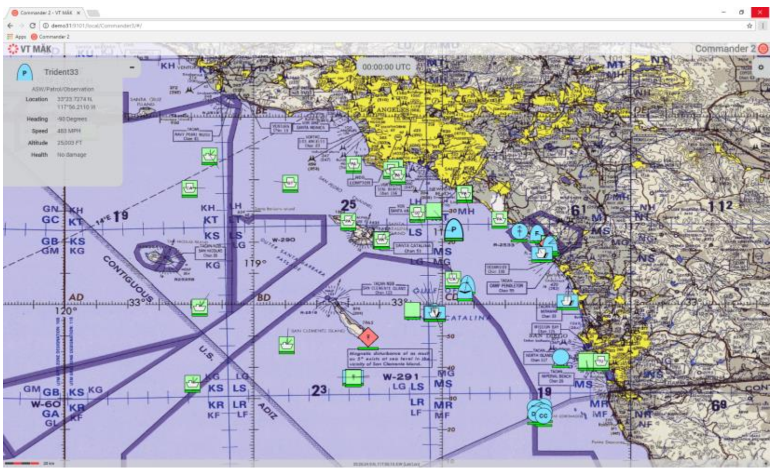

Figure 5: Commander app displaying streamed maps and simulation-generated entities as MILSTD 2525C symbology.

For the 3D viewer app, VT MAK created a new WebStealth app (Figure 6). The WebStealth is an AngularJS, VR-Link.js, and Cesium-based JavaScript application than renders 3D views based on streamed imagery and elevation data. It displays 3D models corresponding to WebLVC-based entities and animations for fire and detonation interactions. Cesium uses WebGL for hardware-accelerated graphics, enabling real-time visualization of terrain and moving models. The WebStealth app provides the following capabilities:

- Interactively pan and zoom to different locations
- Select and display details about entities
- Display shooter-to-target lines
- Display history trails for moving models
- Select and follow entities
- Define and choose different base imagery and elevation layers

Figure 6: WebStealth app displaying streamed imagery, elevation, and simulation-generated entities as 3D models.

DAS transitioned the apps to their internal lab for demonstration and testing. The first phase successfully demonstrated the potential for a suite of products with a single common web-based interface to LVC systems. DAS continues development with their next phase focusing on the development of exercise control and AAR applications that can support the LVC-IA community.

Summary

The WebLVC protocol and streaming terrain technologies, along with other well-proven web frameworks, can provide the foundation to facilitate the process of moving simulation-based training to a cloud-computing environment that can support effective training in a classroom as well as distribute learning across private or public wide-area networks. These technologies can be used separately or in conjunction with other mechanisms to support cloud-based computing. Some examples of alternate approaches which could also support simulations include:

- **Application control via video streaming**. A number of “cloud gaming” systems make use of this approach, in which a player uses a thin-client to access a game that is run on a remote server, and the video results are streamed to the player’s computer. Player’s actions are sent to the server and the effects are displayed in the resulting video stream. There are several video game services that use this paradigm including nVidia GeForce Now among others. VT MAK also has an example streaming video viewer using VR-Vantage to control and stream 3D views without the need for local 3D hardware.

- **Desktop virtualization**. There are a number of services that enable virtual computers to be spawned and accessed remotely. Microsoft has a Remote Desktop built into Windows. Amazon Web Services enables desktops to be defined and provided from the Amazon cloud. The advantage is that a single desktop can be defined and then be accessed by any number of users, centralizing the set-up to the single desktop. However, this approach typically does not support accelerated 3D graphics, often used in simulations. The SAIC Integrated Training Edge (SITE) delivers an approach that enables accelerated 3D graphics, so that a virtual desktop accessed via the VMware client fully supports accelerated 3D graphics rendered remotely without requiring local 3D graphics cards.

Using a combination of web or cloud-based approaches can localize the configuration of an application, terrain, or desktop to a single unit, which can then be instanced and accessed by any number of users remotely. Changes can be made and easily propagated without the need to copy them to multiple computers, reducing the probability of errors and the overall time and effort. By leveraging web services, training systems can improve scalability, enabling any number of trainees to just connect to the exercise, without the need to pre-install any software or data. This approach lowers overall costs and time to set up an exercise, enabling exercises to be run more frequently with less effort.

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[1] Swan, P., *WebLVC - An Emerging Standard and New Technology For Live, Virtual and Constructive Simulation on the Web*, 2014 Winter Simulation Conference, DEC 2014, http://informs-sim.org/wsc14papers/includes/files/475.pdf

[2] W3C HTML5 Specification, https://www.w3.org/TR/html5/

[3] SISO WebLVC PDG, https://www.sisostds.org/StandardsActivities/DevelopmentGroups/WebLVCPDG.aspx

[4] SISO-REF-010, https://www.sisostds.org/DigitalLibrary.aspx?Command=Core_Download&EntryId=45387

[5] Open Geospatial Consortium Standards, http://www.opengeospatial.org/docs/is

[6] Long, R., Pettiford, Y., Overfield, K., *Common Web-Based Interface to a Live, Virtual, Constructive (LVC) Environment Using WebLVC* (2016-SIW-033), 2016 Simulation Innovation Workshop, SEP 2016 https://www.sisostds.org/DigitalLibrary.aspx?Command=Core_Download&EntryId=44935