The Synthetic Environment

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1. Introduction

1.1 Purpose

Understanding the definition of the term synthetic environment, as used in the Modeling and Simulation (M&S) community, is crucial to understanding the SEDRIS project and the problem SEDRIS is attempting to solve. Synthetic environment, as used in today's networked, interoperable, heterogeneous training systems, means more than just the visual scene of the simulated battlespace. This expanded definition for synthetic environment is part of the reason why the SEDRIS project has been initiated. To successfully interchange data describing a synthetic environment, the interchange mechanism must account for all the data types, along with their relationships, necessary to define the total synthetic environment.

This paper presents the SEDRIS definition of synthetic environment and explores how this definition impacts the design of the SEDRIS data model. When completed, this paper will become Chapter 2 of the Synthetic Environment Domain Description Document.

1.2 References

1. Birkel, Paul A., *SEDRIS Geospatial Reference Model*, Draft 0.5, 10 July 1997
2. DoD 5000.59-P, DMSO Modeling and Simulation (M&S) Master Plan, 17 October 1995
3. FAQuest Transcript, STRICOM, 23-24 July 1997
4. Transcripts of Spring 1996 Presentation

2. Synthetic Environment Definition

Today's definition of synthetic environment means more than the visual scene representation it once meant. As used in current training system architectures, synthetic environment means the total simulated representation of the battlespace created to support the training exercise. Two categories of objects are represented in the synthetic environment: the natural environment with its cultural and natural features, and the warfighting entities present in a battlespace. [3] Although some of these objects can be dynamic during the running of a training exercise, SEDRIS is currently only concerned with the static properties of the objects in the synthetic environment.

As defined in the DMSO M&S Master Plan, the synthetic environment covers all environmental domains – terrain, ocean, atmosphere, and space. The Master Plan defines the synthetic environment as the total simulation environment. [2] While this may infer that the synthetic environment would also include the trainee's station (*i.e.,* the interior of a vehicle), SEDRIS limits the definition of synthetic environment to the simulated representation of the exterior features of the training station as well as the features of the natural environment. [3]

The Master Plan states that the synthetic environment is created to allow the visualization and total immersion of the training audience into the environment simulated for the training exercise. The Master Plan further defines the environmental representation as an authoritative representation of all or a part of the natural environment including permanent or semi-permanent man-made (*i.e.,* cultural) features. The mission space, as described in the Master Plan, is the environment containing the entities, actions, and interactions comprising the set of interrelated processes used by individuals and organizations to accomplish mission tasks. The objective of the creation of a training system is to immerse the warfighter in a synthetic environment that accurately simulates the anticipated terrain, environmental conditions and threat. [2]

The definition of the synthetic environment, as used by SEDRIS, is the simulated natural environment usually representing a true, geographic location in the world including the tactically significant natural and cultural features along with the external, physical representations of the warfighting entities.

3. Training System Applications Which Use Synthetic Environment

The expansion of the simulated visual scene representing the battlefield to the all encompassing term synthetic environment is the result of the enhanced capabilities of today's training systems. For many years, a "reasonable fidelity" geographic scene, as viewed by the training audience "out-the-window" of their own-vehicle, was considered a major enhancement to any training system. The only sensors that were affected by this simulated environmental representation were the trainee's eyes. In addition, the level of detail or fidelity of the environmental scene was not required to be great since most training systems using visual scene generators were high-altitude, fast moving aircraft trainers.

As the computational capacity of training systems increased, their sensor simulation capability also increased. Infrared, thermal, laser, sonar, and light-intensification sensors could now be simulated. But, to be simulated correctly, these sensor simulations required data about the simulated environment. Improved computational capacity also increased the number of simulated entities in the training exercise to the point that the instructors and operators of the training system could not continue to manually control each entity. Modeling of these entities to allow automatic dynamic motion and actions in response to the environment was implemented. The environmental representation had to provide data and information to both the sensor and entity models that was different from the data needed to drive an image generator. The expanding requirements of the training systems, brought on by their increased computational capacities, had created a new simulation requirement – the creation of a total synthetic environment with sufficient data representation to support all features of the training system.

Sensor simulation impacted the database for the synthetic environment by requiring data and attributes that reflected the state of the environment as perceived by the sensor's models. The attributes of the existing data types of the synthetic environment used for visual scene generation were not adequate for sensor simulation. For some sensors, new data types were needed as well. The sensor simulation models needed information which differs from the data that represents the natural environment. For instance:

- Thermal sensors can be simulated by presenting displays to the trainees with different color attributes than used for normal views,
- Sonar hydrophone sensors need sound pressure arrival angle information determined by the ocean model,
- Simulated light intensification sensors need environmental data representative of their "view" of the real world,
- Electromagnetic sensors require propagation and location information from sources which may be beyond visual range.

A major impact on the synthetic environment database was the development of Computer Generated Forces (CGF) and Semi-Automated Forces (SAF). CGF entities are totally under the control of their dynamic and reasoning software models. The CGF entities react automatically to the trainees' actions and the environment without input from the training system's instructors or operators. SAF entities also use dynamic and reasoning models, but they take a limited amount of high-level input from the operators. A SAF operator may issue a command to a simulated tank platoon entity to "move down road X and take a defensive position at location Y". Obviously, this simulated entity cannot "see" that the chain of polygons that are gray or black with a yellow stripe down the middle that head in a southerly direction is a road. The model for the SAF or CGF entity must obtain information from the synthetic environment's database that allow it to identify a "road" as well as the road's direction, width, weight capacity, etc. Additional software could be added to the CGF's reasoning and behavioral models to derive the presence of a road from the polygonal data, but this adds unnecessary complexity to the models. The synthetic environment database's developer knows that a linear feature (*i.e.*, a road) is present in this simulated geographic location. This topological data and its attributes that define a road need to be included in the database so the CGF models can use this information directly without having to derive its existence.

Synthetic environment databases have always provided the data used by the image generators to create the visual representation of the geographic area of the training exercise. While new data representation demands were being placed on the synthetic environment by the sensors and CGF simulation models, new visual scene techniques also created new visual data representational needs. Even with the latest computer advances applied to the image generators, the high fidelity requirements of a training system exceed the number of polygons that can be produced in real time by the image generator to create the visual scene. This "polygon count" limitation is dealt with by lowering the level of detail of some of the entities and features of the visual scene. Yet, high levels of detail are needed by the trainees to correctly identify and react to the entities in the visual scene. The number of polygons used to create the visual image of an entity determines the level of detail – the more polygons, the higher the image's level of detail. However, the greater the entity's range from the eyepoint of the trainee, the less detail the trainee can discern. Therefore, entities that are “farther away” can be shown with fewer polygons (*i.e.*, less detail) than entities that are “close” to the trainee. Distant terrain and terrain features can also be represented with fewer polygons. This technique allows the creation of a visual scene that appears to have a high level of detail while keeping the polygon count within the real-time capabilities of the image generators. The affect of this level-of-detail technique on the synthetic environment database is another increase in the data and attribute information. Now, data describing the different level-of-detail models for each 3-D object and terrain feature must be contained in the synthetic environment database.

Another new training system requirement is to generate electronic or paper maps that correlate with the visual scene of the training exercise’s geographic location. This requirement has added another set of new non-visual data and attributes to the synthetic environment’s database. Data types for map generation include unique symbols for map features as well as labels identifying areas by name. Maps also require data for generation of contour lines. Since maps may be produced at different scales, the data in the database must support scale expansion. Once again, new requirements on the training system must be satisfied by increasing the synthetic environment’s database.

Closely coupled to the requirement for maps is the training system requirement for a 2-D, planar view of the battlespace. This Plan View Display (PVD) is used by the instructors and operators to monitor the training exercise. PVD data needs are similar to those used by the map generation function but also include the capability to show the dynamic entities of the training exercise superimposed on the map-like display. These entities require a higher degree of image fidelity to show the entity’s articulated parts as well as the part’s orientation. The PVD must also show the dynamic movement of these entities in the battlespace. A “zoom” capability of the PVD that allows the user to view larger or smaller areas of the battlespace creates additional data representation demands on the synthetic environment database. What features are to be left out, or added back in, as the display is zoomed in and out? At what scale does the display change? As with the other new training system capabilities, PVD data needs must be satisfied by new data types and attributes in the synthetic environment’s database.

The description of the synthetic environment to this point has been from the viewpoint of a virtual training system – a training system where the training audience operates simulated equipment. But the definition of synthetic environment also applies to constructive training systems. In a constructive simulation, the training audience provides inputs to models (*i.e.*, simulations) of simulated groups/echelons directing simulated equipment. This type of training system (essentially a war game) is used for higher echelon command and control training for senior level officers. The training audience stimulates (*i.e*., makes inputs) to such simulations, but is not involved in determining the outcomes. The constructive training system is totally made up of CGF-type models. While there is no direct view of the battlespace by the training audience, the synthetic environment database must represent the environment to the CGF models and provide PVD displays for the training audience. The database of a fully defined synthetic environment is critical to constructive simulations.

The definition of synthetic environment has been expanded to include the data and attributes of all representational “views” of the objects and features encountered on the battlefield. It also includes data types that improve performance by dealing with levels of detail. The data types now found in the synthetic environment database include topology information to minimize derivations of information. While new data types and attributes have been added to the database, a continuing, critical requirement on the database is that all of the data must be correlated and present an integrated, single, coherent representation of the synthetic environment. The data object called a “tree” that is represented as polygon data types for the image generator must correlate with the representation as a topological point feature for the CGF models. The tree that a trainee sees out the window of his vehicle must be the “same” tree (i.e., same location, same height, same intervisibility etc.) that the CGF vehicle is hiding behind. The correlation issue is not only critical for the stand-alone training system, but is extremely critical when two training systems are interoperating on the same training exercise using the “same” synthetic environment.