Conceptual Models for WARSIM 2000

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ABSTRACT

Constructive simulation development requires representing the "real world" which consists of the environment, entities, and tasks. Historically, descriptions of the subject domain have been directly implemented into the simulation. However, the process of repeating this analysis for each new simulation has not proven to be a cost efficient approach.

Conceptual models are first-level abstractions of the simulation's domain. Developing conceptual models results in an implementation-independent repository which can be used by simulation developers that lack domain knowledge. The development of conceptual models requires a knowledge development process, similar to the software development process. The execution of this process results in quality knowledge representation products. These knowledge development products can be validated to insure that they correctly represent the problem domain. The use of the conceptual model in the development of the simulation can be verified through traceability.

A conceptual model called the Functional Description of the Battlespace (FDB) is being developed for the U.S. Army's Warfighter 2000 (WARSIM) system. The bulk of the FDB is made up of behavioral representations used to develop computer generated forces. Behavioral descriptions closely mirror the objects found in the Army domain: units, missions, and tasks. Other critical representations include equipment and the simulated physical environment.

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Modeling and Simulation Subcommittee

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Introduction

Constructive Simulations

There are three basic types of man-in-the-loop simulations: live, virtual, and constructive. Live simulations involve the use of actual equipment, virtual simulations use replicated equipment, and constructive simulations are heavily computational, with relatively little human intervention. Constructive simulations are further characterized by a large number of simulated entities performing behaviors and interacting within a simulated environment. Therefore, the development of constructive simulation requires representing the "real world" which consists of the physical environment, entities, and tasks (behaviors).

Historically, descriptions of the particular subject domain have been directly implemented into simulations. However, performing a domain analysis for each new simulation has resulted in repeating past efforts. This is not a cost efficient approach when simulation domains overlap.

Several large constructive simulation efforts have recently begun. These simulation systems include the U.S. Army's Warfighter 2000 Simulation (WARSIM 2000), the U.S. Air Force's National Air and Space Model (NASM), and the Joint Chief's Joint Simulation System (JSIMS). These wargames are intended to provide training to commanders and their staffs at higher echelons. Sponsors of each of these efforts have recognized the importance of accurately representing their respective domains before developing their simulations and have committed to representing their domain elements in conceptual models.

Conceptual Models

Conceptual models are first-level abstractions of the simulation's domain. Subject Matter Experts (SMEs) create descriptions of the real world with limited influences from how the simulation will be implemented. These descriptions are then compiled into a repository. The repository is accessed by simulation developers to support their domain knowledge requirements, and by validaters to support their activities.

The development of conceptual models requires a knowledge development process, similar to the process employed for developing the simulation's software. The execution of this process results in knowledge representation products. An objective of the process is to produce models which are complete, accurate, and traceable. These products can be validated to insure they correctly represent the simulation's problem domain. The correct use of the conceptual model in the development of the simulation can be verified through traceability.

The purpose of developing a conceptual model is to bridge the authoritative knowledge gap between warfighters and simulation developers by providing descriptions of the real world. Military subject matter experts use their experience with the subject domain to communicate with software engineers/modelers who represent the information in knowledge representation formats. The resulting products are entered in a repository and used by the simulation developers to support the requirements analysis, design, and implementation of their simulation.

Unlike a software logical model, a conceptual model of a mission space is implementation independent. Although complete independence is not practical, obvious implementation-specific descriptions such as algorithms for describing how to simulate something are not included.

The conceptual model is developed based on the domain (see Figure 1). The constructive simulation is developed using the conceptual model. The conceptual model can be validated against the domain, the constructive simulation can be verified based on the conceptual model, and the simulation can be validated directly against the domain.

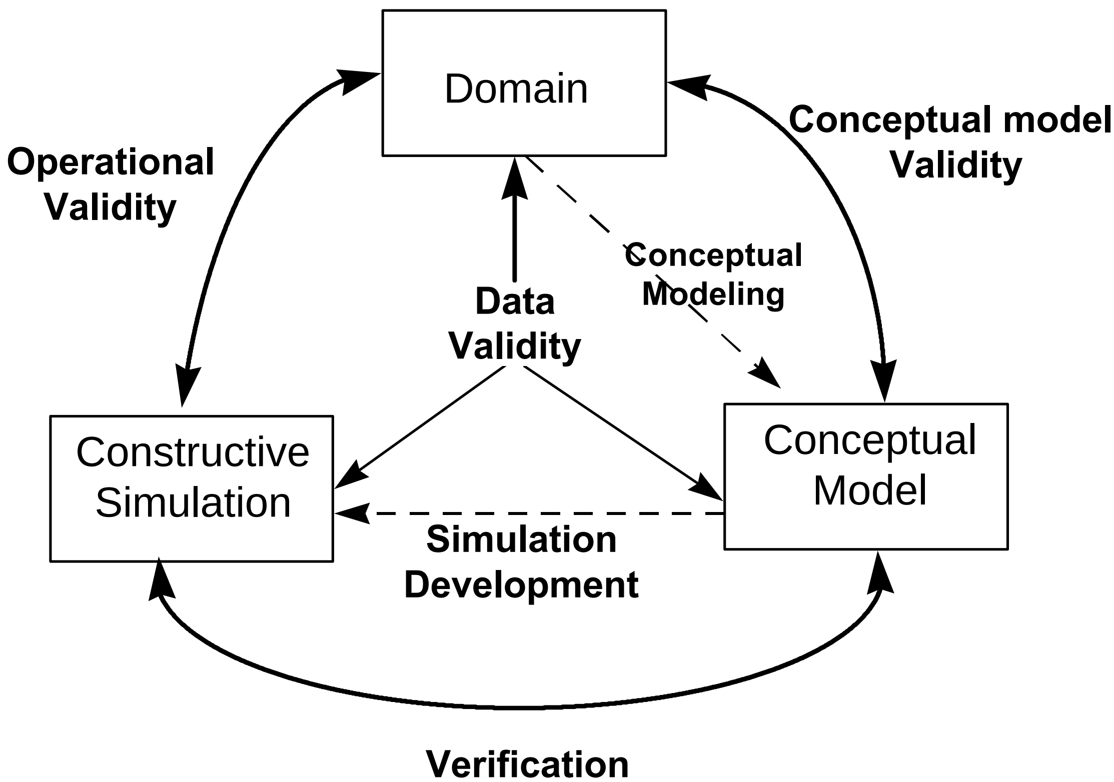

Figure 1. Relationships between the domain, conceptual model, and constructive simulation.

Benefits

The advantages of developing a conceptual model must justify the associated costs. The primary motives for performing conceptual modeling are to reduce simulation lifecycle costs and increase validity and traceability. Benefits should be obtained throughout the simulation development lifecycle.

Early in the conceptual modeling, the scope of the simulation is analyzed to determine the subset of the "real world" that must be included in the conceptual model. The results of this activity help further scope the simulation application.

Throughout the simulation development lifecycle, decisions must be made regarding how to model particular elements of the simulation. The conceptual model provides a forum for communicating decisions for interpreting and simplifying the real world into the simulation. Throughout the simulation development, Verification, Validation, and Accreditation (VV&A) activities should be ongoing. The conceptual model provides a basis for VV&A. The conceptual model can be validated against the real world. Then, by using traceability between software and the conceptual model, verification steps can be performed.

Once the conceptual model is developed, the simulation developers have a readily available traceable source of domain knowledge. This assists in their requirements analysis and design activities. The conceptual model provides a description of the real world that may contain common descriptions or model elements which are reused throughout the conceptual model. This should help simulation developers in identifying common software modules and reuse candidates. Other simulations with overlapping domains with a simulation which has a conceptual model, can benefit by reusing the descriptions of common portions of the "real world".

Background

Realistic constructive simulations require extensive analysis to correctly represent the subject domain.

Traditionally, constructive wargame development has involved incorporating real world knowledge or abstractions directly into the application. Software engineers often visit with SMEs in the field or attempt to interpret written materials to obtain the requisite background knowledge required to develop the simulation. This knowledge is often directly applied ("hard coded") to the development, and the documentation of the knowledge is often haphazard.

Several problems are apparent with this approach including repeating knowledge acquisition efforts, maintenance difficulties, and lack of traceability. Because multiple simulations require similar background knowledge, different programs would obtain similar information independently. Sometimes the data cannot be correlated, leading to integration and interoperability problems. Maintaining the simulation is often difficult because it is unclear what the implications of a change in the real-world are to a simulation. Traceability is difficult because it is unclear where domain knowledge resides in the software and what source was used in preparing critical sections of the software.

The High Level Architecture (HLA) community recognized the need to perform conceptual modeling as part of simulation development (DMSO, 1996). The HLA Federation Development and Execution Process Model (FEDEP) describes conceptual models being used as part of the conceptual analysis phase (Lutz, 1996).

Conceptual Model Development

The development of a conceptual model for constructive simulation requires the creation of a focused context, the acquisition of data, and the representation of knowledge.

Focused Context

Developing a focused context involves selecting a subset of the real world for inclusion in the conceptual model. This is performed by analyzing the simulation application that the conceptual model supports. In the case of constructive simulations for training, the training audience and their training objectives must be considered. This will help identify the subset of the real world required to provide the necessary stimuli to the training audience to achieve the training objective. A major challenge in defining the focused context is to narrow the scope of the conceptual modeling effort while keeping the model as simulation-independent as possible.

Data Acquisition

Once the focused context is determined, knowledge can be acquired to support the description of the focused context. This effort is similar to software requirements analysis and involves reviewing available documentation and interviewing domain experts. Only information from Authoritative Data Sources (ADSs) should be considered.

Knowledge Representation

Acquired data usually needs to be recast into more concise, useful formats for use by simulation developers. These formats must support the simulation developer's requirements for domain knowledge and the validater's requirements for understandable knowledge that be easily validated against ADSs. The simulation developer needs complete descriptions and appropriate levels of detail. The developer also uses the conceptual model to help identify common and reusable components. Description completeness is difficult to judge. Automated tools support the more formal representations.

The identification of common or reusable information is supported by taxonomies. These generalization hierarchies indicate differences at varying levels of abstraction. Granularity trade-offs can be made using the taxonomy.

Common simulation components can often be identified during conceptual modeling. For example, equipment descriptions can be developed by composing representations from representations of subobjects. For example, a model of an F-18 fighter aircraft might be composed from engine models, munition models, and airframe models.

The criteria for distinguishing items in a taxonomy is critical. For example, it would seem natural to separate BLUFOR equipment from OPFOR equipment. However, because of coalition operations and the legacy of Soviet equipment in Eastern Europe and SW Asia, (among other reasons), there is no longer a clear distinction between friendly and opposing force equipment types. Taxonomies also assist in determining appropriate aggregation levels for the simulation.

WARSIM Conceptual Modeling

The U.S. Army's Warfighter 2000 (WARSIM) system is a constructive simulation currently being developed to train commanders and their staffs (NSC, 1997).

A conceptual model is being developed for WARSIM which will be stored in a repository. The repository, called the Functional Description of the Battlespace (FDB), is being developed for Army conceptual models (Pettit, 1997). The bulk of the FDB contains behavioral representations used to develop computer generated forces. Behavioral descriptions closely mirror the organizing constructs found in the Army domain: units, missions, and tasks. Other critical representations include equipment and the simulated physical environment.

Knowledge Development Process

The process of developing conceptual modeling is based on knowledge engineering processes. There are two primary phases: knowledge acquisition and knowledge representation. Knowledge acquisition involves harvesting source documents and interviewing subject matter experts from authoritative data sources. Once this information is collected, analyzed, and filtered, it is recast into knowledge representations.

The focused context and simulation requirements are to document FDB content requirements (see Figure 2). These requirements are to scope the effort of developing FDB contents. The contributions to the FDB are provided to the Government's contractor that manages the repository. Simulation developers then use the information. The simulation developers also refine their requirements on the FDB as they use the conceptual model repository's contents.

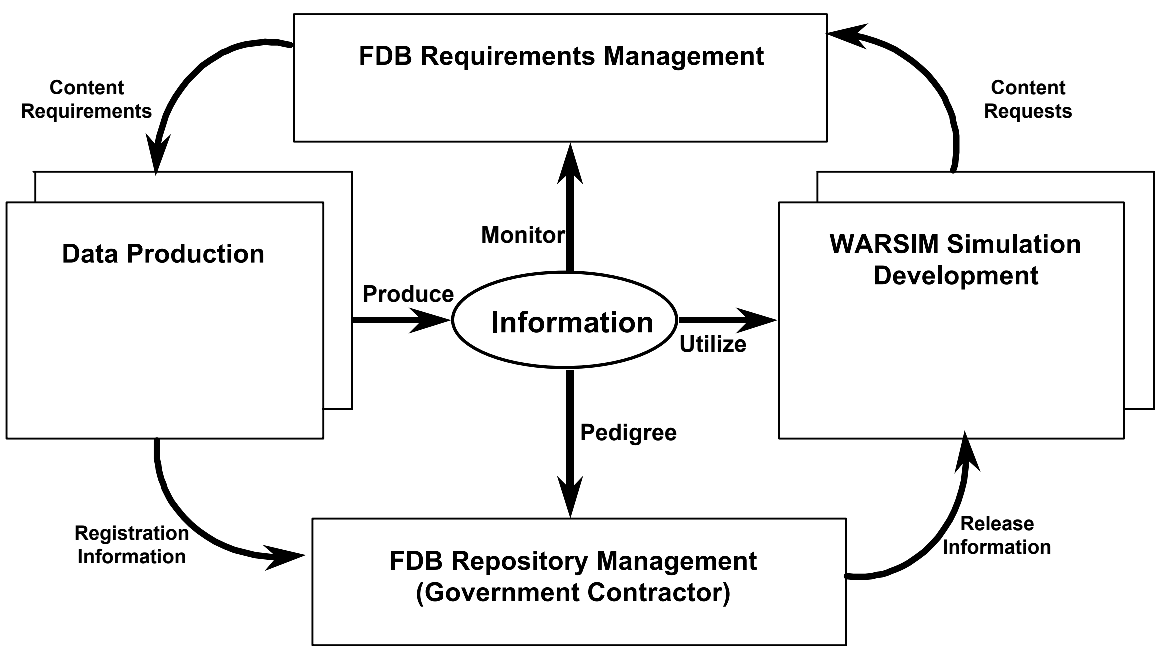

Figure 2. WARSIM Knowledge Engineering Process.

WARSIM Focused Context

A critical step in defining the content of a conceptual model is to focus the context. The Training Requirements Analysis Process (T-RAP) is a U.S. Army effort which helps identify the WARSIM training audience, tasks to be trained, and items to be simulated to support training. The list of items to be simulated scopes the real world domain. The types of information which must be included in the conceptual model are based on the simulation's requirements and are documented in a requirements set called the FDB Content Requirements.

WARSIM Knowledge Acquisition

The WARSIM Knowledge Acquisition activities are performed to support the FDB content requirements. The individuals collecting data are military subject matter experts and engineers employed by the WARSIM contractor team. The SMEs are primarily recently retired U.S. Army officers with extensive knowledge of the domain. Once the SMEs acquire data, information must be represented in formats useable by both simulation developers and validaters.

WARSIM Knowledge Representation

Knowledge must be represented in a clear, unambiguous manner, usable by both simulation developers and validaters. Early in the simulation development process, simulation developers require more generic background information. A useful representation scheme is a free-text white paper. As the development process continues, more specific description formats are required.

Knowledge representations are expressed using languages such as structured text documents and diagrams such as IDEF1X entity-relationship diagrams. One single language or format is insufficient for representing the various types of knowledge. However, a mix of formats can be organized together to fulfill the representation requirements. The following sections describe the WARSIM knowledge representation formats.

Behavioral Representations

Behavioral representations are the most complex and numerous representations in a constructive simulation. They are used by the simulation developers to model the behaviors of the computer generated forces (CGF).

Army unit behavior is described in the FDB in a variety of representations including :

- Unit Models
- Mission/Operation Models
- Task Models

Unit Models describe the organization and purpose of a specific unit. Mission/Operation Models describe the missions that a unit can perform. Mission descriptions include temporal views of the tasks which make up a mission. Task Models provide detailed descriptions of tasks which are performed as part of a mission. Task descriptions contain the bulk of the information required to simulate behaviors.

Equipment Description Models

Each type of equipment to be simulated in WARSIM must be described in the conceptual model. Although constructive wargames are often considered to be modeling at an aggregate level, equipment-level descriptions are needed for a variety of reasons. Some simulations are built "bottom-up". In these simulations, small units (such as a platoons) are formed from a collection of equipment "entities". These small units are then combined with other small units to form larger units (such as companies). Also, some constructive wargames (such as WARSIM) include a 3D viewer. Visual representations and other attributes are required to present a reasonable representation of the battlefield situation. Many of the simulation's requirements may result in equipment-level representations. For example, a requirement to realistically simulate the use of sensors may require the parameters of the object being sensed to determine its effect on the sensor.

Environmental Description Models

Some consider descriptions of the physical environment to be outside the scope of conceptual models. However, if a conceptual model truly describes the real world, a representation for the physical environment must be included. Some conceptual models only represent the objects that make up the physical environment. WARSIM conceptual models will describe these objects as well as the actual terrain.

The Defense Modeling and Simulation Office (DMSO) and the DoD Modeling and Simulation (M&S) Executive Agents for Environmental Representation, in coordination with the U.S. Army Simulation, Training and Instrumentation Command (STRICOM), are developing the Synthetic Environment Data Representation and Interchange Specification (SEDRIS). Although SEDRIS consists of low-level primitives, programs such as WARSIM are using SEDRIS to represent their physical environment, including terrain.

Knowledge Development Plan

The process for developing the WARSIM knowledge representations is documented in a Knowledge Development Plan (KDP). The KDP is similar to a Software Development Plan, and is based on MIL-STD-498. The Knowledge Development Plan defines the activities and tools used to generate knowledge development products. By documenting, maintaining, and following the Knowledge Development Plan, a mature process can evolve.

Summary

Constructive simulation development requires adequate information describing the domain. Conceptual models provide this domain knowledge for the simulation developers. Historically, simulations were developed in a “stove-pipe” manner with redundant knowledge acquisition efforts.

Conceptual modeling provides numerous benefits associated with reducing the simulation lifecycle costs. These benefits include increasing the validity of the resulting simulation, supporting traceability to authoritative data sources, and providing representations to simulation developers and validaters.

The WARSIM knowledge development process describes the processes and tools used to generate knowledge representations. This process is documented in a Knowledge Development Plan.

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