Reasoning, Planning, and Goal Seeking for Small Combat Unit Modeling and Simulation

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Abstract. The current state of Modeling and Simulation (M&S) scenario creation is difficult, requiring too much time and effort on the part of Subject Matter Experts (SMEs) and analysts to produce scenarios that are sufficiently realistic for valid analysis, as well as a need for more realistic M&S agent behavior and decision making in simulation. Additionally, there also is a critical need for decision support tools to support Soldier and Small Unit (SU) decision making in the field. TSE is currently developing algorithms for the automation of combat operation simulation behaviors on the individual Soldier and SU level that may also be leveraged for Soldier and SU decision support tools to meet these critical Computer-Human Interaction (CHI) domain problems. TSE is researching and developing the Reasoning, Planning, and Goal-Seeking (RPGS) architecture, which is targeted at the next generation of constructive simulations requiring autonomous and intelligent agents that are capable of problem solving; considering multiple courses of action; coordinating with friendly forces; following chain of command; and using Tactics, Techniques, and Procedures (TTPs) to guide operations. Intelligent agents guided by RPGS methodologies and algorithms will be able to execute complex tasks given mission goals, initial/boundary conditions, constraints, and access to a battlespace knowledge base. TSE is creating a formal model of the Soldier and SU battlespace on which reasoning can be conducted. TSE will integrate two technical standards into the battlespace knowledge model; the Joint Consultation, Command, and Control Information Exchange Data Model (JC3IEDM) and the Coalition Battle Management Language (C-BML). This paper discusses the application of these standards and the design and development of a battlespace knowledge base and new RPGStechnologies.

Keywords: reasoning, planning, goal selection, autonomous behavior, constructive simulation.

1 Background

Technology Solutions Experts, Inc. (TSE) develops the Infantry Warrior Simulation (IWARS) system for the U.S. Army Natick Soldier Research, Development, and Engineering Center (NSRDEC). TSE is researching and developing algorithms for

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Soldier and Small Unit (SU) combat operation behaviors for use in constructive simulations such as IWARS. The primary goal of this research is to develop methodologies and algorithms for improving the scenario-generation process in simulations by reducing the dependence on textual or graphical scripting languages. Currently, analysts must plan behaviors in great detail in order to construct large, realistic, and valid simulation scenarios with scripted behaviors. Scripting inherently requires the analyst to anticipate every situation that could occur during the scenario and ensure there is a decision process to produce a response. An early result of this research was the creation of a conceptual design for the Reasoning, Planning, and Goal-Seeking (RPGS) framework, a cognitive approach for SU constructive simulation [1].

Currently, TSE is creating new approaches to model agent behavior capable of responding to unanticipated battlefield conditions [2]. TSE's approach is to improve the autonomous decision-making capability of the Soldier agent, which will reduce the analyst's burden of inputting and scripting realistic Soldier and SU behaviors. To this end, intelligent agents are enabled to process assigned goals and to apply cognitive and problem-solving methodologies to assess the situation and to determine, autonomously, the optimal means to accomplish its goals. TSE also is extending this research into the next generation of constructive simulations for intelligent agents that are capable of problem solving; considering multiple courses of action; coordinating with friendly forces; following chain of command; and using Tactics, Techniques, and Procedures (TTPs) to guide operations. The goal is to develop intelligent agents guided by RPGS methodologies and algorithms that can execute complex tasks given only mission goals, initial/boundary conditions, and constraints. These new technologies and capabilities will provide significant contribution and innovation in human behavior representation for military and commercial constructive simulations by reducing scenario construction time and providing more realistic Soldier agent behavior and scenario outcomes.

The RPGS framework has been influenced by the widely used Belief-Desire-Intention (BDI) model [3]. TSE refines the BDI model in RPGS with explicit rule-based reasoning to establish belief, goal-selection rules that reflect desire, and dynamic planning to establish intention.

2 Reasoning, Planning, and Goal Seeking

TSE designed the RPGS framework to allow intelligent agents to complete problem solving, consider multiple courses of action, coordinate with friendly forces, follow chain of command, and use TTPs to guide operations. RPGS methodologies and algorithms allow agents to execute complex tasks given only mission goals, initial/boundary conditions, and constraints, and allow them to access to an underlying battlespace knowledge base.

"Reasoning" is the act of adding new facts to the agent's knowledge base and using these facts to select the agent's goal. This includes perception of the environment, spatial reasoning, and the application of knowledge rules to determine new facts. The battlespace knowledge model is a key component of the RPGS system, providing the foundation for knowledge-based understanding and reasoning. The U.S. Army has invested heavily in the development of battlespace knowledge systems, and TSE is leveraging existing system models including Command and Control (C2) models such as the Joint Consultation, Command, and Control Information Exchange Data Model (JC3IEDM), knowledge portals such as the Army Knowledge Online (AKO), battlespace languages such as the Coalition Battle Management Language (C-BML), and training documents such as the U.S. Army Training and Doctrine Command (TRADOC) Pamphlet 350-70-6 [4].

"Planning" is the process of finding a sequence of actions that will achieve a goal. By understanding and anticipating the outcomes of specific actions and acting with intent, the agent can engage in problem solving, which is difficult with scripted behaviors.

"Goal Seeking" links the reasoning and planning processes to actual behavior, translating planning operators into actions in the underlying simulation. TSE identified the operator precedence selection mechanism that exists in the Soar cognitive architecture [5] as a promising basis on which to design a preference system for action selection. TSE will combine this system with existing technical standards for battlespace knowledge systems such as JC3IEDM [6] and C-BML [7]. Leveraging these systems provides the analyst with a way to express preferences and priorities for agents in determining how to execute mission orders.

3 Battlespace Knowledge

3.1 Battlespace Knowledge Models

JC3IEDM and C-BML are the two technical standards TSE identified for direct integration into the battlespace knowledge base. JC3IEDM is a North Atlantic Treaty Organization (NATO) standard database schema used to enable interoperability of C2 systems, and it is capable of describing many knowledge items of military interest, such as troop locations, materiel, hazard zones, and key events. The JC3IEDM contains three data models: a conceptual data model, a logical data model, and a physical data model. The conceptual model represents the view of information in generalized terms, such as "actions," "organizations," "materiel," "features," and "locations." The logical model breaks these generalized concepts into specific information that follows human reasoning patterns. The physical model is the physical schema that defines the structure of a relational database. JC3IEDM provides an extensible base for representing information about battlefield entities. C-BML, which has already been integrated with JC3IEDM, is a formal language for specifying orders and reports by specifying the "who, what, when, where, and why" of a mission order. C-BML provides an abstracted representation of the information in JC3IEDM that is closer to how humans create plans, using goals and objectives to define final and intermediate results and the mission contingencies that need to be followed. As a formal language, C-BML is well suited for use with the RPGS battlespace knowledge model because it eliminates the ambiguity of free text associated with human-written orders and plans.

TSE will leverage C-BML to describe mission goals and constraints that the analyst gives to agents allowing the RPGS behavior engine to generate autonomous agent behavior.

3.2 Battlespace Knowledge Rules

Battlespace knowledge rules are being developed in the context of JC3IEDM and C-BML. TSE currently is mapping the IWARS underlying information model to both JC3IEDM and C-BML and is discovering the existence of knowledge gaps. TSE is leveraging enabling standards and technologies such as the World Wide Web Consortium (W3C) recommended Semantic Technology standard languages of Resource Definition Framework (RDF), RDF Schema (RDFS), and the Web Ontology Language. These standards and languages are being used to codify behavior rules and a common vocabulary. TSE created a custom triple store, user interface, and integration with IWARS that enables a battlespace knowledge base and the RPGS behavior engine.

4 Conclusions and Future Work

TSE currently is developing the RPGS framework, shown conceptually in Figure 1. The RPGS framework will enable agent behaviors based on inference of the logical consequences of asserted facts or axioms, and the implementation of a set of inference rules specified using a declarative logic programming language. The RPGS Reasoning Engine will perform reasoning using first-order predicate logic and inference through both forward and backward chaining.

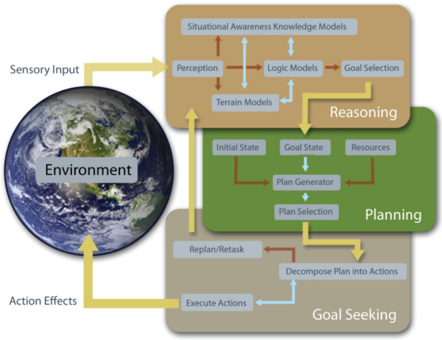

Fig. 1. The Reasoning, Planning, and Goal Seeking Framework

Figure 2 shows how TSE will use its research results to generate the RPGS behaviors. TSE is using JC3IEDM as the common vocabulary to define the tasks, and TSE is using C-BML as the language to express those tasks to the agents. The terrain representation includes semantic information for terrain reasoning and the terrain reasoning algorithms use that information to provide realistic military use of the terrain. Along with military doctrine, the C-BML plans and terrain reasoning will provide the

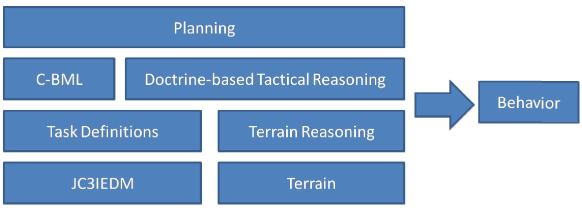

Fig. 2. RPGS Framework to Behavior

overall tactical reasoning that the planning system will use for initial scenario generation as well as monitoring and potential re-planning during mission execution.

The RPGS framework is a promising approach to developing autonomous agent behavior for constructive military simulation. The ability to build reusable, portable, dynamic behaviors demonstrates there is significant potential in improving the flexibility (and thus the realism) of agent behavior. The composition of operations enables users to generate increasingly sophisticated and reusable collections of behaviors.

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