CREATING THE SEMANTIC BATTLESPACE: NARRATIVE STRUCTURE FOR INFORMATION FUSION

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ABSTRACT

The army has identified a need for representations of the battlespace that can be analyzed by both computational systems and subject matter experts to aid the C4ISR (Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance). The Future Combat System (FCS) envisions a seamless merge of information systems and hardware, communicating on the battlespace in real-time with persistent data. Much of the infrastructure of FCS will be supported by the Global Information Grid (GIG); the Department of Defense (DOD) mandated interconnected set of information capabilities for war fighters, policy makers, and support personnel. One of the primary policy requirements on GIG assets is interoperability using common or enterprise-level communications and computing architectures. The multiple data sources, communication channels, heterogeneous platforms, and information systems in FCS will not only generate cognitive overload to the war-fighter, but will make information fusion difficult. The problem is context; how to add semantics to the data to assist decision makers and battle planning.

The purpose of this paper is to highlight the narrative approaches that are inherent in several ongoing Army efforts. Recognizing the storytelling nature of these systems and the potential for automated contextual enhancement will leverage the significant research in narrative from other disciplines. Incorporating M & S systems with C4ISR applications, particularly the Future Combat System (FCS), will necessitate a multi-disciplinary approach to making seamless communications with automated systems.

1. INTRODUCTION

The army has begun to focus on the problem of adding context to the vast amounts of information on the digital battlefield. There are extensive databases and repositories containing information on command and control, force structure, logistics, planning, and MOOTW (Military-Operations-Other-Than-War). The army leadership involved in these activities would like to take advantage of lessons learned from previous situations, decreasing the cognitive overload of dealing with multiple forms of information. Utilizing this context on the battlespace will require ontologies, metamodels, and frameworks for organizing the data.

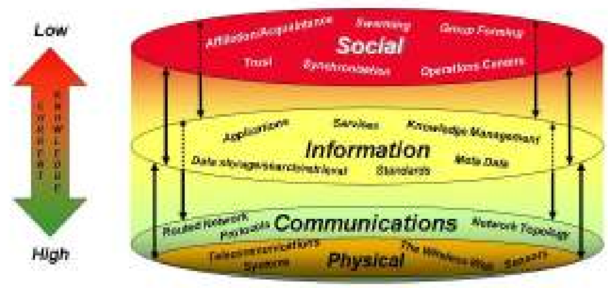

Figure 1 Vertical Information Fusion

The problem is one of information fusion. Information fusion is the concept of decision-making and inference by gathering disparate pieces of data. Most of the focus has been on accomplishing *horizontal* fusion, where organizations attempt to share across domain boundaries, adding to increased understanding for all parties and a clearer view of the "big picture". Within the battlespace, containing differing levels of need-to-know and bandwidth to process data, actionable intelligence is going to require *vertical* fusion. As seen in Figure 1, there are several layers of data, with corresponding technological approaches, that model the needs in the battlespace. Currently, there is a high level of expertise at the physical layer; personnel, sensors, networks, and software applications can gather digital data efficiently, with increasing accuracy. However, interpreting that data and deriving higher-level meaning

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(a necessity for battle planning and analysis) is extremely difficult to accomplish, requiring knowledge of intent driven by social, cultural, and organizational goals. Information that moves from local nodes (boots-on-the-ground) to global sources/sinks (higher echelons) will require complex narratives with greater contextual underpinnings.

The well-known radio journalist and on-air personality, Paul Harvey, had a recurring segment of his show called "The Rest of the Story" (Aurandt, 1984). He would supply a teaser statement about some event or person prior to a station break, pledging to fill in the background information later. The added details and contextual information would always lead to a compelling, entertaining, and frequently surprising twist to the tale. In a similar fashion, narrative techniques can be used to complete the stories that are inherent throughout the battlespace. Information moving from global sources to locals nodes leave out details, balancing the conciseness of the data against the complexity (and bandwidth) required for completeness. However, many of these details can be introduced to the data flowing to global sinks, given sufficient knowledge of the domain being described. Performing this narrative generation with automated systems requires capturing domain knowledge in a machine-readable form. It also requires a consistent, agreed upon representation of the vocabulary and concepts of the domain. This knowledge is contained within ontology.

Ontology is a formal explicit description of concepts in a domain of discourse, the properties of each of those concepts, and restrictions on those properties (Crubezy and Musen, 2002). The discussion of ontology has its roots in the philosophical focus on describing the reality of existence. It was Aristotle who said that "there is only one bed" – meaning that the fundamental notion of a bed remains consistent no matter how the specific pieces are put together. In his *Metaphysics*, Aristotle outlined his "science of being" to deal with the nature and organization of reality. Just as he viewed ontology as a way of describing the static concepts of existence, Aristotle considered narrative as a natural framework of the world in action. In his *Poetics*, Aristotle described what he felt was a recurring dramatic plot structure. All (effective) dramatic stories could be subdivided into this structure. This connection between ontology and narrative is a natural method for describing reality and giving it context.

2. WHY EXAMINE NARRATIVE?

Mateas and Sengers coined the term *narrative intelligence (NI)* to describe the cognitive ability of capturing knowledge through narrative (Mateas and Sengers, 2003). Essentially, narrative intelligence means that we think in stories. As an organizing principle for human experiences, NI draws from multidisciplinary definitions of narrative, such as art, psychology, cultural studies, literary studies, and drama. NI researchers are concerned with designing narrative interfaces, agents that interact through narrative, storytelling and story-understanding systems. Kerstin Dautenhahn, of the University of Hertfordshire, proposed the *Narrative Intelligence Hypothesis*, which views narrative as a necessity in the development of complex social structures (Dautenhahn, 2001). Dautenhahn claims that communicating through narrative evolved as social dynamics became more complicated.

Some influential cognitive scientists propose that narrative is central to models of explanation and inference. Jerome Brumer described the characteristics of narrative that separate it from random phrases in a language (Brumer, 1991):

- Narratives describe sequences of events using human time, rather than real-time
- Narratives are about unusual events that are worth telling
- Narratives describe characters, with intentions, interacting in a setting that supports their beliefs
- Narratives require a plot, with a higher meaning

Roger Schank, a prominent researcher in the field of artificial intelligence, felt that stories are essential to learning and understanding. Schank modeled cognition in terms of *scripts*, mental templates that the mind executes based on the situation and environment (Schank, 1977). He also attempted to define generalized classes of actions, creating categories like *mtrans* to denote the mental transfer of information and *ptrans* to describe actions that involved a physical change of location.

Narrative is also reflected in cognitive science notions of mental models and thought experiments. A *mental model* is an internal representation of the outside world (Johnson-Laird, 1983). A *thought experiment* is a hypothesis testing process where a person visualizes a sequence of events to determine a possible outcome

(Scott, 2000). If the internal visualization is a sufficiently reasonable model of the environment under which the events occur, the outcome will illustrate possible solutions to the problem.

There have been several previous efforts at developing abstractions of narrative. Propp's *Morphology of a Folktale* was an effort by a 20th century literary scholar to create a hierarchy and structure of the standard folktale, as a basis for analysis (Propp, 1968). Propp identified recurring patterns within the genre and built relationships between the patterns and the form of the folktales.

Joseph Campbell and Carol Pearson examined the concept of myths and storytelling as societal or cultural metaphors. Campbell's work is widely known as a treatise on the use of myth to explain the values and principles from a civilization. Examining how a group creates its mythos gives greater insight into what motivates their world. In *The Power of Myth*, Campbell talks about the goals and characteristics ascribed to heroes and how they are a microcosm of people in general (Campbell, 1988). Pearson focuses on the protagonist of stories, defining a series of archetypes for categorizing goals and motivations (Pearson, 1989). A protagonist is the character that drives the plot and initiates the action. The antagonist is a character that attempts to block the goals of the protagonist. An archetype is defined by Pearson as "deep and abiding patterns in the human psyche that remain powerful and present over time". Pearson relates archetypes to phases of psychological development or personality type.

The Semantic Web is a project, sponsored by the World-Wide Web Consortium (W3C) that supports information exchange by creating documents with computational meaning. Tim Berners-Lee, the creator of the Web, describes the Semantic Web as "…a web of data that can be processed directly or indirectly by machines" (Berners-Lee, 2000). The Semantic Web is evolving through the use of standards, markup languages and processing tools. Just as there is an effort to create a Semantic Web, it will be necessary to create a *semantic battlespace*. There are ongoing army projects that seek to add semantics to the battlespace. These efforts will assist with adding context to the battlespace through ontological approaches, capturing knowledge from army domains and encoding it in machine-readable form. Narrative will enhance these tools because it represents a dynamic view of ontology. The simplest definition of narrative is "character in action". The semantic battlespace will require "ontologies in action"; not just definitions of concepts, rules, and relationships, but canonical stories of the interactions between the concepts.

3. NARRATIVE-BASED APPROACHES WITHIN THE ARMY

There are several Army projects that have at their core a narrative approach for understanding and analyzing information.

3.1 Modeling and Simulation

The Institute for Creative Technologies (ICT) grew out of a study commissioned through the National Research Council (NRC) and sponsored by the Department of Defense (DOD). The goal of the study was to determine how to merge the efforts and capabilities of the entertainment industry with the M & S needs of the military. The mission of ICT is to develop synthetic environments and immersive technologies for training, analysis, and operational systems. ICT has become one of the army's leading proponents of training M & S. There is a strong narrative aspect to many, if not most, of the projects under development at ICT. Three such systems are the Mission Rehearsal Exercise (MRE), the Army Excellence in Leadership (AXL) project, and the game simulation Full Spectrum Warrior (FSW).

The MRE is a virtual reality environment that seeks to immerse trainees in the sights, sounds, and stresses of real-world scenarios (Swartout et. al., 2001). Using speech recognition software, the user interacts with the characters, attempting to complete mission objectives through persuasion and negotiation. These virtual humans can act as friendly forces, civilians, or antagonists while simultaneously coaching the participant's decision making. In order to make the simulation tractable and minimize the complexity of AI reasoning necessary, there are three types of virtual humans: scripted, AI-based, and AI-based with an emotion model. Scripted characters have a limited range of behaviors and functionality in the story, similar to the "extras" in a filmed narrative. AI-based characters are the ones that directly interact with the trainee and, therefore, must be able to reason about and interpret changing situations. Narrative is about context, assigning goals and obstacles to explain the actions of characters in a story. The third type of character uses an emotional behavior model to modify their perceptions, objectives, and receptiveness.

Creating dramatic, compelling storylines is central to the effectiveness of MRE. The trainees' level of engagement is enhanced by including stress and uncertainty into scenarios. The participant must be not only knowledgeable with standard military protocol, but must have some familiarity with the local culture of the inhabitants in the simulated environment. MRE even incorporates a crowd behavior model that can be adjusted to exacerbate an already tense situation.

The AXL project uses filmed narratives of leadership scenarios to support an interactive case method of training (Hill et. al. 2004). The storytelling of fictional case studies, highlighting specific leadership obstacles and requirements, guides leader development by creating "what would you do?" situations for analysis.

One of the most successful army training simulations based on gaming technology is Full Spectrum Warrior (FSW) by ICT. FSW was an attempt to merge the familiarity and accessibility of a commercial gaming platform (Microsoft's Xbox) with a squad-level cognitive training simulation (Korris, 2004). The tool relies heavily on narrative and immersion to establish mission objectives and training guidelines. The back-story of the game involves MOUT (Missions Over Urban Terrain) in a generic southwest Asian nation.

An interesting aspect of FSW's transition to a commercial video game and its subsequent popularity is the unconventional method of play. Unlike most combat-centered role-playing games (RPGs), it is not a first-person shooter. In other words, the participant does not carry or directly fire a weapon. As the squad leader, the player accomplishes his objective by giving orders associated with specific game controls. The squad leader controls two fire teams, alpha and bravo, that are programmed to emulate the standard tactics, techniques, and procedures (TTP) of a small infantry unit. (Figure 2) Doctrinal behaviors (such as bounding overwatch, directing fire in sector, and suppressing fire) are automatically accomplished by the squad, with appropriate movement and in realistic formation. The individual entities on the fire teams are not only given particular roles (team leader, automatic rifleman, rifleman, grenadier), but are given specific identities and personalities.

For the commercial version of FSW the artificial intelligence in the game engine had to be scaled back to increase the vulnerability of the opposing forces (OPFOR). The adaptability of the unmodified OPFOR made the game harder to defeat and, therefore, not as appealing to the commercial gamers who are used to games where pattern recognition and repetition are the key to success.

Figure 2 Screenshot from Full Spectrum Warrior

3.2 C4ISR

The Command and Control Information Exchange Data Model (C2IEDM) evolved from a need for unambiguous definitions of entities on the battlespace (Turnitsa and Tolk, 2005). As a common reference model, C2IEDM supports the interchange of data between command and control information system (C2IS) databases. The need for C2IEDM grew out of problems of interoperability between systems during joint exercises. The Multilateral Interoperability Program (MIP) Organization member states, which include over two dozen NATO (North American Treaty Organization) or affiliated countries, sought a common specification for C2 data compliant with level 5 interconnection standards.

The narrative aspect of C2IEDM is related to its ontological construction. Currently, there are over 190 entities which contain the concepts in the C2IEDM ontology. There are two structural types within the relational model of C2IEDM: objects and actions. *Objects* are the persons, places, or things that represent the classes or categories of items on the battlespace. *Actions* are the tasks and events that can occur between entities and external to their interactions. Although a C2IEDM system does not contain complete narratives of the battlespace, the behavior and activities of each entity are describe extensively through its corresponding action tree. The action trees describe the objectives of an activity, the effects, whether the tasks are planned or unplanned, current status, and whether other tasks are functionally or temporally related. It is not difficult to imagine constructing coherent narratives of the battlespace using C2IEDM object and action building blocks.

Another army effort at capturing domain knowledge is Battle Management Language (BML). BML is defined as an unambiguous language used to command and control forces and equipment conducting military operations and provide for situational awareness and a shared, common operational picture (Carey et. al., 2001) The purpose of BML is to standardize the terminology and symbology of the battlespace based on doctrinal information, allowing automated C4I systems and stakeholders to interact.

C-BML (Coalition Battle Management Language), a current incarnation of BML, leverages work from the OIPT, C2IEDM, and other C4ISR efforts (Blais et. al., 2005). C-BML is to improve situational awareness by introducing consistency in the discourse of the battlespace, allowing automated simulated and robotic forces to interpret and respond to commands. The same five W's that are the basis for storytelling (Who, What, When, Where, and Why) can be represented with C-BML. The CBML group is collaborating with the development of MSDL to insure that the standards will be consistent.

MSDL (Military Scenario Definition Language) is an effort to create a standard interchange format for military M & S systems. Most simulations have some form of scenario script or language, but these representations are either proprietary or platform dependent. The definition of MSDL will support C2 simulations with an international standard for data representation and file transmission, usable by live, virtual, and constructive simulations (Surdu et. al., 2005).

4. AN XML SCHEMA FOR NARRATIVE

From the previous narrative-based approaches and cognitive research, it would be safe to assume that a machine-readable form of the narratives could enhance problem solving. To create such a computational narrative form, it would be necessary to describe the ontology of narrative. This is the basis of this research effort. The ontology was defined by capturing concepts from different narrative forms. The resulting framework led to the creation of the hyperscenario grammar and specification language. The *Hyperscenario Framework* consists of the scenario ontology, grammar, and an XML-based language (Hobbs, 2003). SCML-S (Scenario Markup Language-Schema) is a language implementation of the narrative ontology.

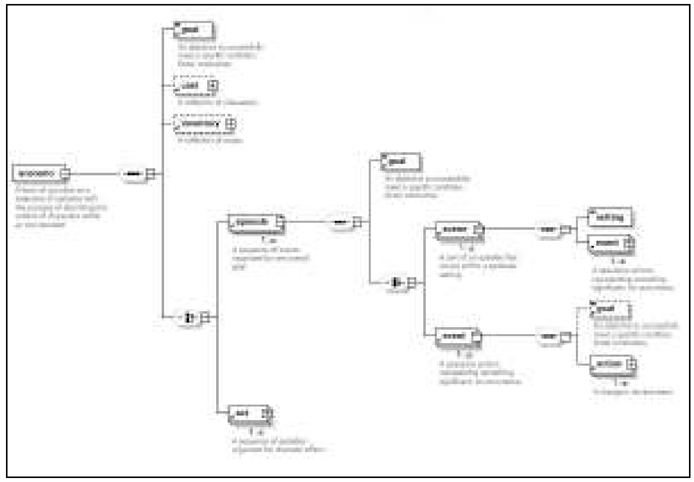


Figure 3 SCML-S Language Structure

Figure 3 is a structural view of the SCML-S schema. SCML-S tags correspond to the concepts and rules from the scenario ontology. Rules for combining and nesting tag elements are derived from the associations, multiplicities, and cardinalities represented in the conceptual model. The design of the schema version of SCML focused on the anticipated instance documents and the potential authors of instance documents in the language. The ultimate goal was adherence to an open, extensible architecture while incorporating more narrative features in the language.

This narrative schema provides a textual, non-proprietary, platform-independent representation of scenario information that can be used by a wide range of military decision-making activities. By using military doctrine to assign context to narrative constructed from multiple data sources, lessons learned can be exchanged between M&S and C4ISR systems.

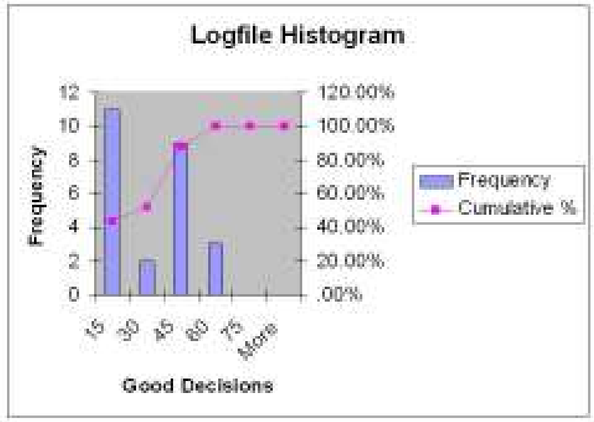
A web-enabled simulation was developed and used as the experiment platform for statistical analysis of SCML and precise measurements of the usefulness of narrative-directed decision-making (Johnson-Laird, 1983). With the availability of the framework and language, an empirical study needed to be done to validate the impact on problem-solving. The purpose of the experiment was to confirm the hypothesis that computer-readable narrative would improve decision-making. The experiment had to be sufficiently self-contained as to describe a manageable number of actions, events, and episodes for analysis.

Two experiment groups, the Logfile group and the SCML group, were supplied with the same amount of information during iterations of the simulation. The display of the data captured for each group during game sessions differed. The difference in representation of the data was *declarative* versus *narrative*. The *declarative* view showed a session as a reproduction of the actions in the maze, just as they occurred. A *narrative* view presented a plot-structured view of the data; a story description of the events and episodes.

There were several performance metrics that were tracked or calculated during game play that were used to evaluate the decision-making patterns of the players. Decision-making can be inferred by examining how resources were used during the game, e.g., the number of moves, the amount of time used, the total points accumulated, etc. Solving the maze was based on the willingness of the participants to trade one resource for another.

The evaluation of the experiment results was based on mapping the decision patterns in each session. As with any problem-solving activity there are moves that constitute good decisions and bad decisions, given the context for the choice. The maze domain is sufficiently self-contained to anticipate the context of actions and determine when a decision maps to a useful strategy. Although there are an almost infinite number of actions that could be performed in a finite time during a game session, there are a finite number of decisions that could lead to a successful completion of the game. The list of good decisions was used during statistical analysis to compare the strategies between the two groups.

The relative frequencies of decision-making are another view of how participants in each group fared during the experiment. Figure 4 depicts histograms of frequency data for both experimental groups. A *histogram* shows the distribution of data as a cumulative effect. Each bin in the histogram is a count of the number of participants that fell with a certain range. For example, bin fifteen is a count of all players with between zero and fifteen good decisions. Referring to the Logfile group histogram at the top of the figure, it can be seen that there were more players who had fifteen or fewer decisions than any other category. This is also true for the SCML group. However, the cumulative affect is different based on the percentage of total players represented by the bins. Eighty-eight percent of the participants on the Logfile group had forty-five or fewer good decisions, while one-third of the SCML group had more than forty-five good decisions.



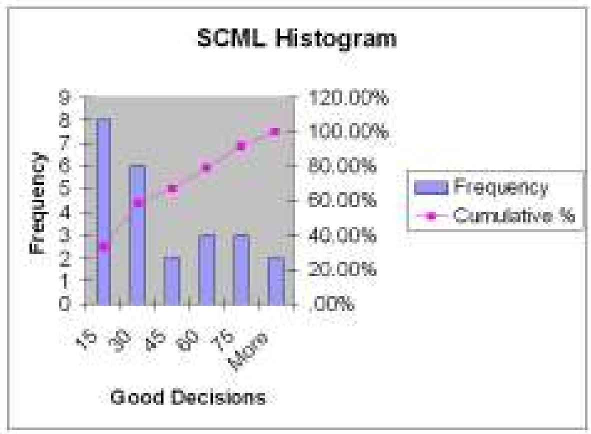


Figure 4 Maze Decision Frequency Distributions

5. CONCLUSION

The use of narrative in all the forms mentioned in this paper will lead to the creation of narrative repositories; digital libraries of stories within different domains. The question is how will these narrative-based representations of information assist the Army and make the semantic battlespace possible? The TCDL (Technical Committee for Digital Libraries) outlines several technical challenges for the development of digital libraries as collective memory (Neuhold, 2002). These challenges map well to the potential uses of narrative on the battlespace.

- Storage: A stories-as-documents approach is an alternate technique for storing information in document-oriented XML databases. This storage will support military-relevant information retrieval.
- User Interface: Data transformation and story manipulation using XSL can create flexible

- user interfaces that support multiple formats, direct manipulation, content-oriented queries, and browsing based on annotations.

- Classification and Indexing: Classifying information is an attempt to collect data in a manner that is intuitive to the user or a specific group. The reason that even ontological approaches to classification are difficult is that the meanings are still domain specific. However, the ability to navigate through story-based archives using criteria such as genre, theme, style, and plot could help automate the process.

- Presentation: There are multiple XML technologies and initiatives, such as VoiceXML, SVG (Scalable Vector Graphics), and SMIL (Synchronized Multimedia Integration Language), that could be used to customize presentations from narrative digital libraries.

Along with the continued refinement of SCML-S, there are other narrative research and development tasks at ARL. The design of an SOA (Service Oriented Architecture) compliant narrative service for the battlespace is being examined. The integration of the cognitive modeling architecture ACT-R (Adaptive Control of Thought – Reasoning) (Gonzalez, 2003) with SCML-S to use pattern matching and military doctrine to create canonical stories for the battlespace. Multimodal storytelling will result from XSL-T (XML Stylesheet Language – Transformation) parsers for mode generation. Finally, the narrative ontology is being ported to OWL-S (Web Ontology Language – Schema). OWL-S, the successor to DAML+OIL (DARPA Agent Markup Language + Ontology Inference Language), is a standard for representing ontologies on the semantic web (Horrocks, 2002).

Philosophers have used both ontology and narrative as methods for describing and interpreting existence. In the multidisciplinary field of cognitive science, narrative figures prominently in models of cognition and views of intelligence. Computer scientists have embraced ontologies for domain modeling and scenario-based design for user-centered software development. There are current army projects that are implicitly or explicitly using narrative. Seamless, net-centric systems, like FCS, will require the development of a semantic battlespace; machine-readable formats that can be interpreted by automated systems as well as domain experts. By leveraging the multidisciplinary work on narrative from cognitive science, entertainment, and film theory, the semantic battlespace will become possible.

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