Automated Reasoning Across Tactical Stories to Derive Lessons Learned

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ABSTRACT

The Military Analogical Reasoning System (MARS) is a performance support system and decision aid for commanders in Tactical Operations Centers. MARS enhances and supports the innate human ability for using stories to reason about tactical goals, plans, situations, and outcomes. The system operates by comparing many instances of stored tactical stories, determining which have analogous situations and lessons learned, and then returning a description of the lessons learned. The description of the lessons learned is at a level of abstraction that can be generalized to an appropriate range of tactical situations. The machine-understandable story representation is based on a military operations data model and associated tactical situation ontology. Thus each story can be thought of, and reasoned about, as an instance of an unfolding tactical situation. The analogical reasoning algorithm is based on Gentner's Structure Mapping Theory. Consider the following two stories. In the first, a U.S. platoon in Viet Nam diverts around a minefield and subsequently comes under ambush from a large hill overlooking their new position. In the second, a U.S. task force in Iraq diverts around a biochemical hazard and subsequently comes under ambush from the roof of an abandoned building. MARS recognizes these stories as analogical, and derives the following abstraction: When enemy-placed obstacles force us into an unplanned route, beware of ambush from elevation or concealment. In this paper we describe the MARS interface, military operations data model, tactical situation ontology, and analogical reasoning algorithm.

Keywords: performance support, decision support, automated reasoning, analogical reasoning, tactical stories

1. INTRODUCTION AND BACKGROUND

The Military Analogical Reasoning System (MARS) is an innovative approach to helping military commanders interpret unfolding situations in light of lessons learned by prior commanders in past situations. The project is developing software technology to enhance and support the innate human ability for using stories to reason about complex situations. The goal is to support reasoning about current tactical situations in light of stories about past tactical situations. Achieving this goal requires success with four sub-goals. First, we must develop a way to formally represent stories about prior tactical situations, with known outcomes so that they can be stored, searched for, and retrieved by machines. Second, we must develop a way for human subject matter experts, who are not software developers, to efficiently input stories that reflect their experiences and lessons learned in tactical situations. Third, we must implement reasoning algorithms that enable machines to not only understand these stories but to also reason about individual stories across multiple stories. Fourth, we must develop a way for the system, upon receipt of situation data from sensors, to use those data to infer a formal representation of the emerging tactical situation, thus achieving situation awareness. Only then will the system be able to select which among the prior stories are relevant to the current emerging story and identify what the relevant prior stories might have to say about the current one. We are currently in the third phase of the project. This project is supported by the Defense Advanced Research Projects Agency (DARPA).

2. STORY INPUT METHODOLOGY

The Battle Story Builder component of MARS provides a way for human subject matter experts, who are not software developers, to efficiently input stories that reflect their experiences and lessons learned in past tactical situations.

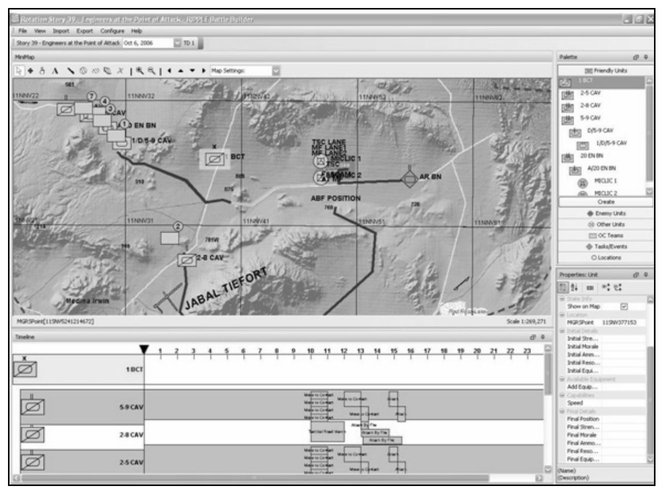

Figure 1. Battle Story Builder Interface - Populating a Story Model

Stories that have been entered in the system using the Battle Story Builder (Figure 1) are saved as records in the Tactical Story Data Model (Figure 2). The entities in the Tactical Story Data Model are rendered meaningful via reference to the Tactical Story Ontology.

3. TACTICAL STORY DATA MODEL

Figure 2 shows some of the more significant entities and relationships from the Tactical Story Data Model, which provides a standard set of entities and relations for representing the kinds of objects, actors, events, and relationships that make up tactical stories. The Data Model can represent anything that can happen in a tactical situation, including blue force commander's intent, opposing force commander's intent, setbacks, surprises, and outcomes.

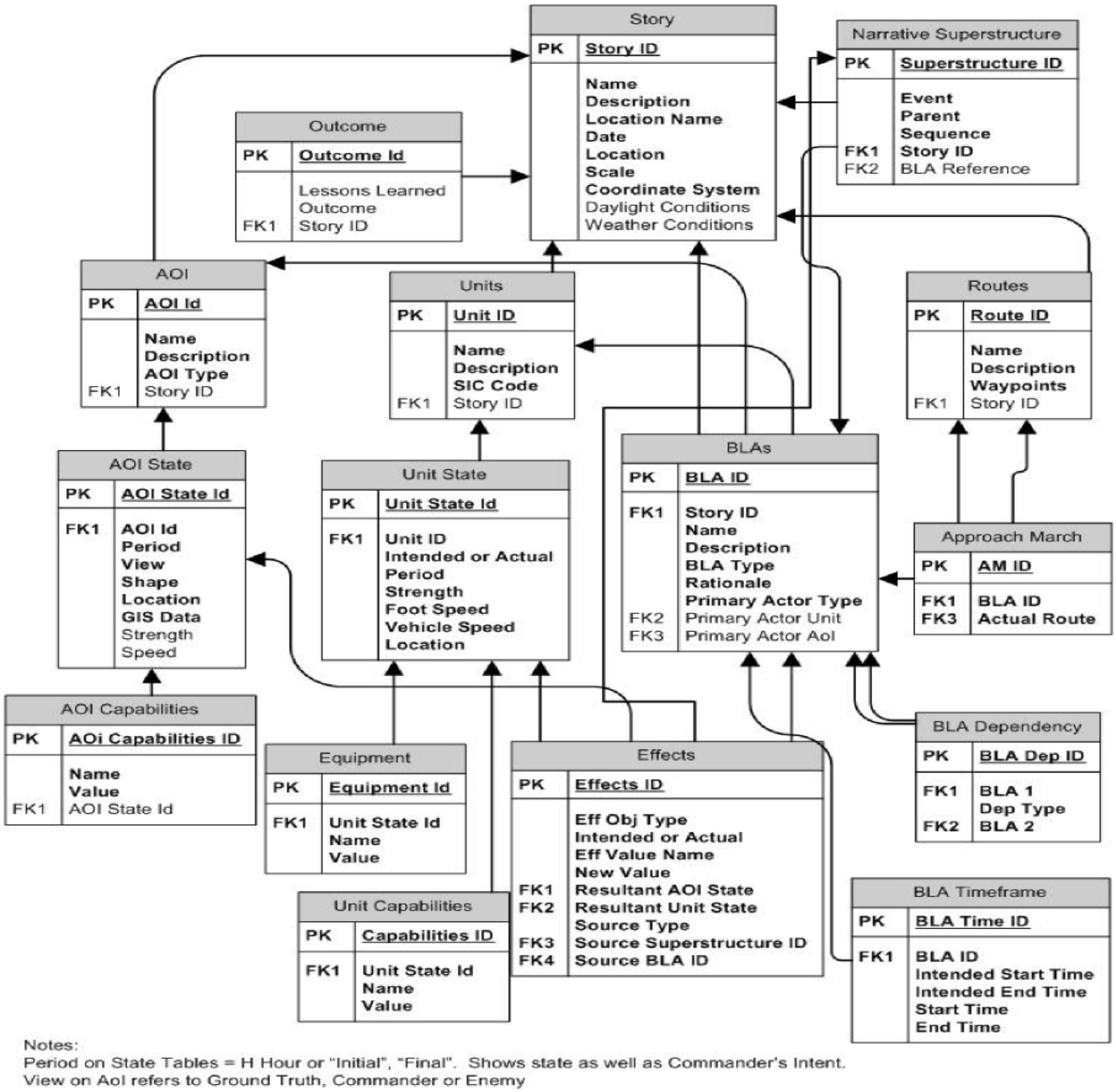

Figure 2. Tactical Story Data Model

4. TACTICAL STORY ONTOLOGY

The Tactical Story Ontology is an extension of the Tactical Story Data Model in that it formally represents the "meaning" of tactical story components. It is implemented in Web Ontology Language (OWL) using Protégé. The ontology captures the "meaning" of tactical stories by extending the Tactical Story Data Model in two ways. First, it links to upper ontologies and associated ontologies to allow machine understanding of what entity names actually mean, and what can be assumed based on that meaning. Second, it formally specifies what relationship names actually mean, and what they imply.

5. ENTITY AND RELATIONSHIP EXTENSIONS

The ontology allows MARS to "know" what an M1 Abrams tank is, including its armament, range, vulnerabilities, and other tactically relevant characteristics. It also allows the machine to know that a tank and certain field artillery pieces are both examples of medium range theater weapons that support ballistic or direct delivery, and kinetic or combustive projectiles. The relationships in ontologies are formally specified, so that machine logic can be applied to determine the implications of relations. In ontologies, relations must be formally specified in order to support machine reasoning, including (but not limited to) first order predicate logic.

6. REASONING ALGORITHMS

The current demonstration release of MARS, focuses on reasoning by analogy. To draw an analogy is to claim that two distinct things are alike or similar in some respect that is interesting, useful, or insightful. Analogical arguments take the following form.

(Premise 1) Object X and Object Y are similar in having properties Q1 … Qn. (Premise 2) Object X has property P.

(Conclusion) Object Y also has property P.

Doing analogical reasoning on stories requires two processes: story comparison and story selection. Forbus, Mostek, and Ferguson [2] describe efforts to automate story comparison and selection. In their approach, story comparison is based directly on structure-mapping theory [3]. In structure-mapping theory, an analogy match takes one base-structured representation and one target-structured representation and returns as output a set of mappings. These mappings constitute correspondences between base items and target items. The matching system also returns a set of candidate inferences, which are inferences about the target made on the basis of the base representation plus the correspondences. The approach to story selection starts with initial comparisons using an easy-to-accomplish "cheap" match based on surface characteristics called content vectors. This initial step produces a smaller set of stories that can then be subjected to more rigorous story comparison.

One of the test cases for the approach described by Forbus et al. is a course-of-action analogical critique system that generates feedback about military plans based on prior military operations. This test case has a goal similar to that of the MARS system. MARS should be able to answer two questions: "How can this group of stories help us better understand Story A and solve Story A's problems?" and "How is Story A like Story B?"

Analogical reasoning appears to be a cognitively easy task for human beings, and is known to be very difficult to automate, or to accomplish with software. Our approach to this difficult problem is to simultaneously apply two artificial intelligence techniques to the problem of finding relevant stories in real time: analogical reasoning across stories and ontological reasoning within stories. Analogical reasoning will be used to compare two stories, that is, two structured representations, which we will refer to, following Forbus and Gentner [1], as base and target. In a simple story comparison, the question to be answered is, "What does this story tell me about that one?" Simple story comparison compares only two stories, both stored rather than live. The story selection process, searching a corpus of stories, poses the question, "Which among these many stories can tell me something useful about this unfolding target story?" Advanced story comparison answers the question, "What do these few selected base stories tell me about this unfolding target story?" Advanced story comparison differs from simple story comparison in that it compares multiple stories, and the target story is live and unfolding rather than stored. Both simple story comparison and advanced story comparison draw analogies among structured, formal representations of stories.

We maximize our chances of success in this difficult domain by 1) building on the significant body of research in the area done by Forbus, Ferguson, Gentner, and others, and 2) limiting initial efforts to stories about a reasonably constrained and well-understood realm: tactical military situations.

Eight story vignettes have been entered into the Story Data Model to test this reasoning approach. Consider the following two stories, shown in Figures 4 and 5.

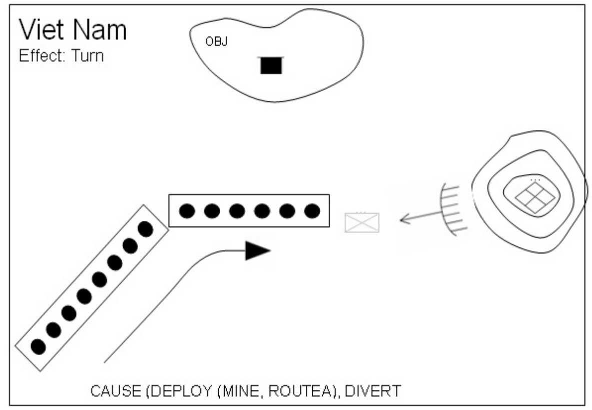

Figure 4. Viet Nam Turn Effect Vignette

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In Viet Nam (Figure 4), a U.S. platoon (blue) is moving towards Objective Fox, which is a tunnel complex being used by the Viet Cong to store weapons. They encounter a minefield in their path, and the commander decides to go around the minefield. This decision brings them into a valley with a large hill overlooking the valley. They are then ambushed by a Viet Cong platoon (red) positioned atop the overlooking hill. In retrospect it is clear that the minefield was placed there to cause the platoon to divert into the kill zone for the planned ambush.

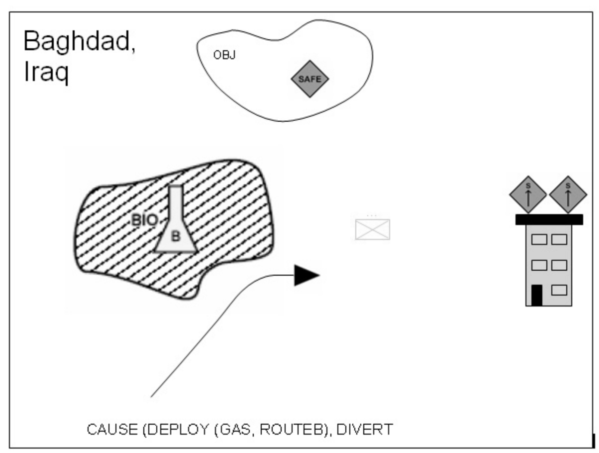

Figure 5. Iraq Turn Effect Vignette

In Iraq (Figure 5), a U.S. platoon (blue) is moving towards Objective Fox, which is an insurgent safe house. The lead vehicle is a biochemical-sniffing HumV, and it alerts the commander to the presence of a biochemical hazard (e.g., anthrax spores, gas, etc.) in their path, and the commander decides to go around the hazard. This decision brings them down a street with several two- and three-story buildings that appear deserted. They are then ambushed by two insurgents (red) positioned atop one of the buildings with rockets and machine guns. In retrospect it is clear that the biochemical hazard was placed there to cause the platoon to divert into the kill zone for the planned ambush.

The two story vignettes are analogical since in each case the enemy knows what the objective of the U.S. forces is, and places an obstacle in their path in order to divert U.S. forces into a kill zone overwatched from a concealed, elevated enemy position. The lesson in both cases is that one should be wary upon confronting anything that causes one to abandon a planned attack route, especially if the alternate route brings one under observation from elevated positions. The MARS Story Comparison view is shown in Figure 6.

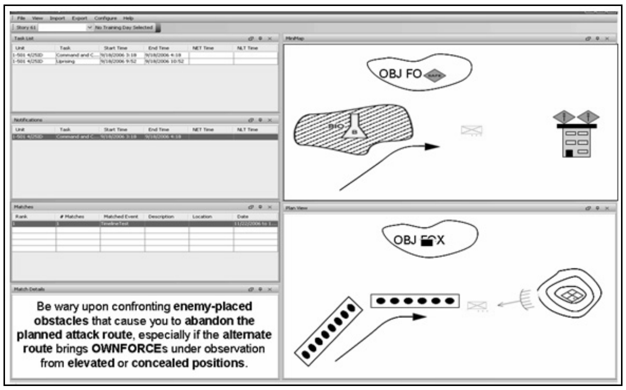

Figure 6. MARS Story Comparison Interface

The current version of MARS supports selecting a target story and displaying the story's diagrammatic map. After the next phase of research, MARS will support display of an unfolding tactical situation as a diagrammatic map. In Figure 6, one stored story has been selected as the target story. The system searches for other stored stories that are analogous to the target story. It orders the returned stories as a function of how analogous they are to the target story. The Match Details section of the display describes the abstraction that links the two stories. In the current situation, displayed in MiniMap, the blue forces commander should be wary of the possibility that the opposing commander is seeking to drive blue forces into an ambush from an elevated location.

7. CONCLUSIONS

The importance of delivering this type of capability to our military forces cannot be overstated. Unlike the Cold War era, when massive firepower and manpower were ready to meet similarly massive forces in pitched[1] battle, many of our casualties today are being caused by primitive weapons in the hands of nontraditional forces. The insurgents and terrorists we fight today avoid at all costs any semblance of a pitched battle, because of our overwhelming superiority in that venue. For the foreseeable future, intelligence gathering and analysis, enemy behavior understanding and prediction, and clever planning are going to be at least as important as traditional military force on force capabilities. Information exploitation and knowledge-based analysis are both important keys to our national security, and MARS can contribute to the solution in these areas.

8. REFERENCES

[1] Gentner, D. and Forbus K. (1991). MAC/FAC: A model of similarity-based retrieval. Proceedings of the Cognitive Science Society.

[2] Forbus, K., Mostek, T., and Ferguson, R. (2002). An Analogy Ontology for Integrating Analogical Processing and First-Principles Reasoning. AAAI/IAAI, 878-885.

[3] Gentner, D. (1983). Structure-mapping: A theoretical framework for analogy. Cognitive Science, Vol. 7, 155-170.

[1] A pitched battle is a battle where both sides choose to fight at a chosen location and time and where either side has the option to disengage either before the battle starts, or shortly after the first armed exchanges.