INTELLIGENT DECISION SUPPORT OF SUPPORT AND STABILITY OPERATIONS (SASO) THROUGH SYMBOLIC VISUALIZATION

LIANA SUANTAK, FAISAL MOMEN, and JERZY ROZENBLIT

Dept. of Electrical and Computer Engr., University of Arizona, Tucson, Arizona, USA 85721

MICHAEL BARNES

US Army Research Laboratory, AMSRL-HR-MY, Ft. Huachuca, Arizona 85613

TED FICHTL

The Compass Foundation, 2017 Chantilly Dr., Sierra Vista, Arizona 85635

Abstract

The Advanced Tactical Architecture for Combat Knowledge System (ATACKS, formerly known as ABATIS) has been designed as a visualization tool to support commander's decision-making in a complex battlespace environment. ATACKS expands standard battlefield symbology by providing symbols for Stability and Support Operation (SASO) on three dimensional (3D) abstract battlespace terrains. Furthermore, it extends normal spatial visualization through process centered displays that seek to enhance the commander's understanding of the situation by presenting qualitative data in novel formats. In addition, external decision support tools communicate with ATACKS through an application program interface (API) that can allow communication over a network as well as between systems on differing operating systems. With this capability, ATACKS can serve as an integration point for intelligent aiding systems.

1 Introduction

Visualizing future battlefields is an important objective for the 21st century Army. Technological advances promise a knowledge-rich battlefield with virtual planning, multi-modal visualizations, disbursed operations, and highly intelligent automated systems. Too often the role of the future soldier and in particular the commander is ignored [1]. Obviously, the effects of visualization will cascade over the entire battlefield and influence both the common and specialized views of the battle at all echelons. Yet the demand for improved technology outpaces our understanding of the benefits of the various techniques [2].

The purpose of our work is to develop an understanding of the theoretical and empirical underpinnings of visualization research and to suggest a human-computer architecture based on synergy between the two components. Visualization is probably one of the most important human capabilities subsuming understanding and creativity. It is a bridge between human knowledge and "seeing" new solutions. However, our ability to visualize is based on heuristic processes that have cognitive costs as well as benefits. Synergy must be based on designing for both our cognitive strengths and limitations.

Visualization has become a ubiquitous term that has attained the imprecision that usually accompanies overuse. Information visualization refers to a graphical transformation of a concept or process into the spatial domain for display purposes whereas the dictionary defines visualization in terms of mental processes " to form a mental image of something not in sight" [13]. The latter definition is close in meaning to both the psychological meaning of forming a mental model [6] and the Army's official definition which defines visualization in terms of the commander's art: *The process whereby the commander develops a clear understanding of his current state with relation to the enemy and environment, envisions a desired end state which represents mission accomplishments, and then subsequently visualizes the sequence of events that will move his forces from the current state to the end state.*[5] This meaning is profound because it suggests an understanding of the battle process and not simply a mechanism for forming an image of the battlefield. For example, Ulysses S. Grant [8] was able to picture various tactical possibilities including likely Confederate responses while planning with the aid of an unadorned map.

Visualization is then an ability to form a mental model of a process that leads to understanding and prediction. Unfortunately, simply understanding

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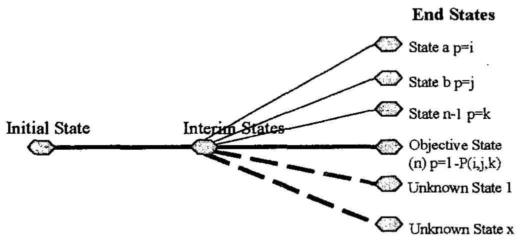

Figure 1. Visualization states in deterministic, probabilistic, and complex problem spaces.

a process does not guarantee a veridical prediction. Even an accurate representation of a process is imperfect in the sense that most processes are not deterministic but uncertain and perhaps even more unfortunately often chaotic in nature. Figure 1 is an attempt to represent visualization formalisms in terms of a mental model of an initial state, transformation processes leading to interim states, and a set of end states. The heavy black line posits a deterministic system that if perfectly described, results in a single end state. The thinner black lines describe a probabilistic model with n possible end states of which the objective state is but one alternative. Even that is an optimistic portrayal of most complex environments wherein unknown factors can result in multiple unexpected events (dashed lines). While no combat problem space is purely one of these alternatives, it is useful to address visualization aids in terms of deterministic, uncertain, and complex processes because different perceptual and cognitive processes are involved in each case.

2 Requirements for a human-computer architecture

The above model suggests that the purpose of computer visualization is more than aiding the operator in understanding the current environment or even understanding an unfolding process. Successful visualizations systems must represent not only the current process but also software that can evaluate future states and generate visualizations that impart insight allowing the user to envisage unexpected situations. In this paper we present a generalized visualization architecture (ATACKS) tailored to these criteria. We discuss three components of ATACKS delineating the necessity of each component in order to maintain the required flexibility: representational, algorithmic and computational. Representation is the traditional emphasis for computer visualization research – that is how to best instantiate the underlying data to present current and possible future states.

Algorithmic issues are purposely isolated from the representational issues in ATACKS to give the architecture the flexibility to explore different techniques and even the use of multiple techniques simultaneously using the same representational structure. An example is our coupling of the representational power of ATACKS with a genetic algorithm developed at the University of Illinois [12]. The FOX-GA algorithm investigates many thousands of courses of action for a military planner and chooses the distinctly best options based on a war-gaming logic module and a niching algorithm. However, ATACKS uses only the outputs of the FOX-GA algorithm and combines these solutions with other rule-based systems [11] to drive the visualization software. Thus ATACKS is being designed to interface with various algorithmic approaches and is not itself a collection of predictive algorithms. The third component will use computational and rule-based approaches to predict the results associated with different courses-of-actions (COAs) but is decoupled from the predictive algorithms because its chief purpose is to evaluate possible algorithmic and human solutions both in term of probabilities and consequences (attrition). This decoupling gives ATACKS the power of a synergistic enterprise by evaluating both human and computer solutions. The human can run multiple visualization simulations comparing the computer solutions to his or her own solutions using both representational and computational software to evaluate the results. Thus ATACKS' principle advantage over traditional AI approaches is that it is interactive rather than prescriptive. It is this interactive quality of visualization that we hope will be most useful for complex environments such as Kosovo and Somalia where unpredictability is inevitable. We are designing representational schemas for these types of environments with ethnic, political, logistical and previously learned lessons being configured to give insight into peacekeeping and other non-conventional operations. Our goal is to create a flexible software environment that is based as much on human knowledge and insight as on traditional software approaches.

3 ATACKS – Basic Architecture

ATACKS contains three distinct general layers: 3D spatial representation of the situation, process displays that present abstract representations of data, and the decision support layer that can provide and evaluate COAs, as shown in Figure 2. The process displays use the information from this layer to display a variety of abstract information, such as unit effectiveness, impact alertness of an event, or suggested support units. The middle layer manages the data of the current situation. The lowest layer (decision support passes information about the current state of the battlefield to decision support tools and then forwards the results or interactions required back to the middle layer.

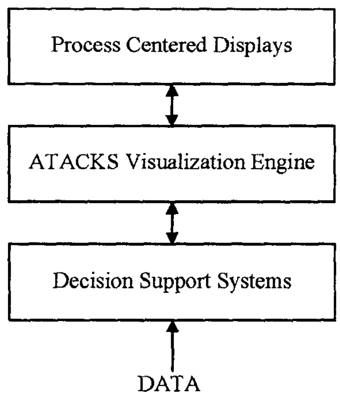

Figure 2. ATACKS Architecture

The fundamental design concept of ATACKS is the modularity of display elements. Terrain and unit elements are represented by symbols (objects) that can reside in libraries and can be placed on the display at any location and in any orientation. As opposed to the traditional paradigm of incorporating attributes and methods in object descriptions, we provide behaviors of battlespace elements by associating with them distinct, dynamic model components. To increase the level of resolution to be visualized we can replace the link associated with a battlespace element from a less detailed model component by a more detailed one.

The process centered display requires simple, fundamental classes from which instances of battlespace representations of any complexity can be rapidly constructed. More specifically, such classes are: a) terrain, b) unit, c) behavior, and d) information (attributes). Unit objects can be built from elementary graphical elements (for example, to construct a 2D-battalion symbol, we can use a rectangle, diagonals, and two vertical bars). New elements (with a more complex structure) can be created from the existing elements and stored in libraries. Thus, reuse and rapid construction of battlespace instances is facilitated.

The prototype of the ATACKS design has been implemented on the Silicon Graphics Octane machine, in C++ using the Open Inventor development environment. The following points briefly summarize the system's major capabilities:

- **initialization methods**: load terrain elements, military units, and tactics into a scenario creation area, import any 3D model specified in the Open Inventor format,
- **manipulation methods**: construct objects from fundamental graphical elements in the object creation window, replace a terrain or unit fundamental element, transfer fundamental elements from the object creation window to scenario window, dynamically specify length and width of terrain size and scale objects and grid size,
- **behavior methods**: attach a behavior model to a fundamental element in scenario window, animate objects through simulation of attached models, and view evolving scenarios.

4 Process Centered Displays

The spatial displays of units' relative positions on a given terrain can convey a great deal of information to the commander. However, some aspects of the current situation can be enhanced by other displays. ATACKS features several "process centered displays" which depict abstract representations of the current situation. For example, a combat effectiveness display shows the relative position of a friendly unit, along with a color-coded indication of the unit's strength and size ratio to any enemy units within its vicinity. The current PCDs also show alerts, logistical information, and suggestions for support units.

One of the main objectives of ATACKS is to study the effectiveness of different types of displays on commanders' decision-making. Therefore, we will continue to create and test many types of displays, such as multivariate displays, displays of large data sets, and symbolic (vs. numerical) displays. The major challenges in creating meaningful displays are determining relevant information and defining appropriate metaphors. It is also important the displays should provide overviews of data without losing specific information.

5 Stability and Support Operations

In the past, military operations have mostly consisted of engaging a well-known enemy to reach a well-defined goal. Military doctrine for these operations was codified in rules regarding logistics, strategy, and attrition rates. Post-Cold War military operations have been very different, and often more complex. Operations known first as peacekeeping missions, then as OOTW (Operations Other Than War), are now known as SASO (stability and support Operations). These missions also include providing humanitarian aid such as distributing food and medicine and ensuring elections security.

SASO operations differ from conventional warfare in several important ways. In SASO, most operations occur in urban areas. There is also no clear enemy. Instead, hostilities may be initiated by several of many warring factions. Allegiances change quickly, and even civilians can turn hostile. The rules of engagement may change throughout different sectors, and the overall political climate may affect appropriate actions.

ATACKS incorporates several SASO features: SASO symbology, urban terrain features, and battlefield rules. SASO symbology includes various symbols that notate units, facilities or activities such as propaganda, demonstrations, refugees, and many others. As well as the conventional warfare units, the ATACKS library contains SASO symbology. The terrain library also includes urban features, such as residential, commercial and government buildings. The advantage of ATACKS is that the user can import objects drawn elsewhere. Therefore, uses can build a detailed urban terrain featuring SASO symbology.

6 Sample Scenario

A sample scenario has been created to demonstrate the enhanced displays to highlight important SASO information such as regional alerts and indicators of the political situation. This scenario illustrates some of the possible conditions that could lead to application of SASO rules and the respective results of the application of those rules. The military action in this scenario has been framed as a three-phase operation: entrance, MOUT, and stability phases. The animated scenario shows the entrance phase in which a brigade is airlifted into an urban airport. From the airport, three battalions move into the urban areas of the city, setting up three battalion sectors. Along the way, each battalion encounters SASO-type situations, including a minefield, an ambush and a hostile crowd. In each type of situation, ATACKS is able to determine what type of encounter has occurred and applies consequences to the involved units, based on rules determined by an external decision support system. It then presents the commander with different types of process centered displays suited to that situation. A snapshot of this scenario appears in Figure 3.

7 Conclusions and Future Work

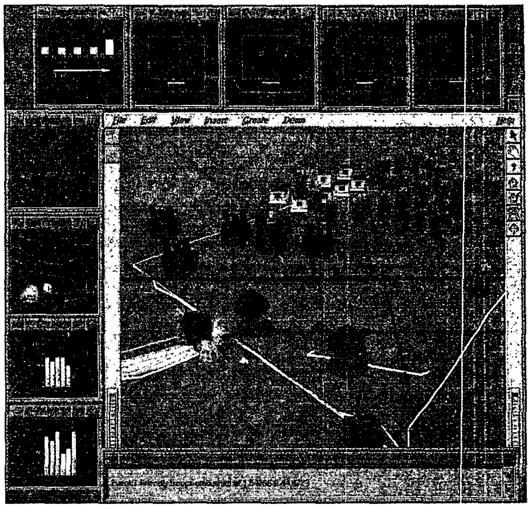

Figure 3. A friendly unit is ambushed

ATACKS provides 3D visualization and integration with decision aiding tools capabilities in a modular, efficient environment. It also provides flexibility in object and scenario creation, as well as in decision support integration.

Future Work on ATACKS will consist of enhancing the existing functionality: creating more library objects, defining more information that can me shared through the API, and extending the user interface. We are also in the process of porting the software from C++ to Java.

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