Visualization of Blue Forces Using Blobology

William Wright and Thomas Kapler

William Wright (POC)
Oculus Info Inc.
55 Havelock St., Toronto, Ont.
Canada M6H 3B3
bill.wright@oculusinfo.com

Thomas Kapler
52 St. Lawrence St., Suite 211
Toronto, Ont.
Canada M5A 3N1
tkapler@rogers.com

Paper submitted to:
2002 Command and Control Research and Technology Symposium,
June 11 - 13, 2002.

Topic Track: C2 Experimentation

Visualization of Blue Forces Using Blobology
William Wright and Thomas Kapler

William Wright
Oculus Info Inc.
55 Havelock St., Toronto, Ont.
Canada M6H 3B3
bill.wright@oculusinfo.com

Thomas Kapler
52 St. Lawrence St., Suite 211
Toronto, Ont.
Canada M5A 3N1
tkapler@rogers.com

Abstract

Several innovative visualization techniques have been developed during the DARPA CPOF program. This paper discusses one technique that became known as "blobology" and which is used to represent self-reporting friendly forces. Blobs evolved over time, in a collaboration with subject matter experts, and this evolution is shown. The experience gained, as these representations were iteratively developed and tested since the program began in 1999, is reviewed. A break-through came with a fundamental shift from a top-down representation of aggregations to a bottom up entity based representation of individual capability.

Introduction

The Command Post of the Future (CPOF) is a DARPA program that aims to increase the speed and quality of command decisions. One CPOF theme has been the development of tailored visualizations that provide immediate understanding of changing battlefield situations. While several innovative visualization techniques have been developed during the DARPA CPOF program, this paper is a report on the major milestones and experiences in the development of one technique that has been called "blobology".

Displays in use today are 2D, static and saturated with inefficient graphics. Examples are shown in Figures 1 and 2. They include the traditional 2525A symbology (FM 101-5-1) more suited to 18^{th-} and 19^{th-}century linear formations and an era of massed formations. Today's displays may actually mislead the commander as to true combat power. "Icons are going to kill us. They are center of mass only." is the view of Maj. Gen. T.E. Donovan, USMC, on the traditional rectangular symbols. Typically, the commander must explicitly reject the appearance of the space occupied by the forces on current displays. Instead, the commander must create and then hold in his mind force composition, disposition, terrain, the temporal dimension and many other factors.

The need for superior displays will increase in the future as commanders will be inundated with information from multiple sources including a vast array of sensors and collection platforms. It is impossible for humans to cull through such a massive quantity of information in order to make decisions in a reasonable amount of time. While machine reasoning will be useful in some areas (e.g. mechanical control of robotic

Figure 1 – Icons on Paper Map

Figure 2 – Icons on Digital Map

systems), automated command reasoning will not be able to process the wide variety of situations, cope with uncertainty, and correctly interpret unexpected surprises, all in a timely manner Therefore, the only way for commanders to maintain situation awareness, execute current operations, and plan future operations in the midst of this flash flood of information is through information visualization.

Information Visualization

Two and three-dimensional computer graphics can be extremely expressive. With the correct approach to the visual design of the layout and the objects, large amounts of information can be quickly and easily comprehended by a human observer. We do not need to simplify the displays and limit the amount of information transferred from sensor and information processing systems to our personnel [Ferren, 1999]. Further, by using motion and animated interaction, it is possible to use graphical displays as reliable, accurate and precise decision-support tools.

Visualization is an external mental aid that enhances cognitive abilities [Card, 1999]. When information is presented visually, efficient innate human capabilities can be used to perceive and process data. Orders of magnitude more information can be seen and understood in a few minutes. Information visualization techniques amplify cognition by increasing human mental resources, reducing search times, improving recognition of patterns, increasing inference making, and increasing monitoring scope [Card, 1999], [Ware, 2000]. These significant benefits translate into system and task related performance objectives, for individuals and groups, such as those shown in Table 1.

Performance Factor	Description
Display Density	More objects and attributes are shown on the screen.
Economy of Interaction	Fewer selections, commands, controls are required.
Number of Displays / Screens	Fewer displays and / or screens are required.
Speed	Tasks are completed in less time.
Accuracy	Tasks are completed with fewer errors.
Completeness	Tasks are completed based on more information.
Training	Less training is required.

Table 1 – Some Visualization Performance Factors

These performance factors affect the completion of comprehension, decision-making and communication (message composition, message reception) tasks. The time, effort and number of work products required to do these types of tasks is reduced.

Information visualization can be difficult to apply. Mapping data to visual form requires knowledge of graphics design and the task domain as well as visualization techniques. Subtle flaws in design can eliminate performance improvements and even diminish performance over traditional tools and methods. Poor graphics design will obscure the data and its meanings. Few visualization principles exist and progress is made by experienced talented practionners. Edward Tufte [1983, 1990] articulates several best practices well. According to Tufte, excellence in graphics consists of complex ideas communicated with clarity, precision and efficiency. Graphical displays should induce the viewer to think about the substance, present many numbers in a small space, make large data sets coherent, encourage the eye to compare different pieces of data and reveal the data at several levels of detail from broad overview to the fine structure.

Development Methods

Our CPOF visualization effort to date has been in design, development and experimentation. Work has proceeded through iterative phases. Collaboration with subject matter experts (SMEs) has been essential to the progress made.

Sketches and Realistic Prototypes
Actual visual expressions provide tangible forms that users, the project team, and various stakeholders can see, understand and with which they can react. Design sketches precede development of prototypes. It is critical that prototypes should be operated by real users, performing real tasks. It is also important to use realistic data so that users can engage in substantive thinking without being distracted by artificial placeholders.

Iterative
The development of blue force representation proceeded through a series of stages. Sketches and prototypes elicit further requirements, and thoughts. Issues are discussed and probed in order to find the less obvious but important cognitive models that make a visualization intuitive. Lessons learned are acted upon and reflected in the next iteration.

User Focused
Military information visualization is more complex than often appreciated because while visual artifacts aid thought, they are completely entwined with cognitive action. In addition, to make progress requires dealing with fundamental issues such as what constitutes combat power, and in what circumstances. Combat power is not just counting people or equipment. It involves tangible and intangible factors. It is never absolute and is always relative to the enemy, time, the place and other factors. Effective information visualizations require appropriate representations for particular domains and tasks. An iterative, creative collaborative research approach with users is necessary for success.

Experimental Evaluation
Continual testing of candidate techniques with representative users has been the practice. This testing ranged from small informal discovery experiments to large more formal experiments. The experience to date has been that small informal experiments are efficient for rapid and reasonably accurate feedback for development purposes. Tactical decision games were used [Schmitt, 1994]. In some cases, simulation-based decision experiments provide near operational-like assessments. Larger more formal experiments are necessary to provide stronger evidence of performance.

Expressive Creativity
A visual dialogue and visual vocabulary can be inspired by analogies, experimentation, play or artifacts observed within the existing work environment. It is necessary to try different approaches and then evaluate effects. Subtle variations in visual techniques can make critical differences in reading and effectiveness. Careful tuning and testing is necessary. Good information visualization representations capture the essence and nature of objects and relationships efficiently and with power. The objective is to discover natural symbolic connections between properties of what's being shown, and how it's being shown. So for instance, using an outline to represent unit footprint is intuitive, while a status pie circle (personnel, ammunition, fuel, weapons) is arbitrary and not intuitive.

LOE 1 Results

Limited Objective Experiment #1 (LOE1) was a major experiment conducted in the fall of 1999 by EBR Inc. The authors provided a number of treatments for LOE1. Figure 3 shows one treatment, a representative blob treatment, for a force-on-force scenario that featured red brigades against blue battalions. The blobs were circular. Their radius represented organic weapons range and their thickness represented aggregated combat power based on unit values as estimated by the scenario author. Blobs joined or merged if their rings overlapped. Air combat power did not contribute to the blobs and was shown at the edges of the 3D terrain.

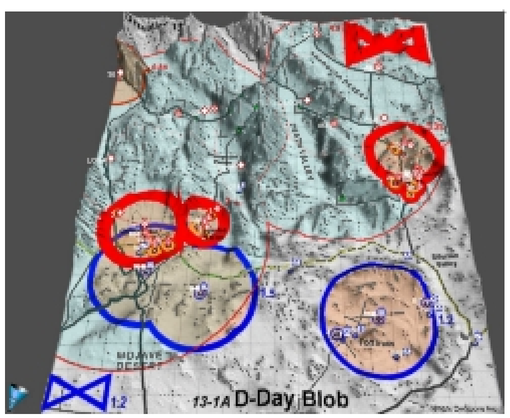

Figure 3 – LOE 1 Blobs

About 40 subjects participated in LOE1. They had a limited time to view previously unseen treatments and then were debriefed with a questionnaire to assess their comprehension of the force-on-force situations. The control treatment was the traditional 2525A symbols on a paper map. The visualization treatments provided significantly greater situation awareness especially in more complex situations. However, it should be emphasized that only a small set of situations were tested involving legacy forces and “mech-in-the-desert” scenarios.

BP4 and BP5

The “Block Parties” (BP) allowed trials of new visualization treatments with fewer subjects. Tactical decision game scenarios were driven by a controller and one or two subjects used the displays to gain situation awareness and make command decisions.

Blobs evolved in a number of ways for BP 4 and 5 in 2000 in order to better depict more “see-shoot-sense” force attributes. See-shoot-sense attributes help answer questions such as these. What can I see and not see? What can I hit and not hit? Figure 4 shows non-uniform edge thickness which provided greater fidelity for strength disposition and orientation. Figure 5 shows red blobs fading over time as new position updates are received. Additional visualization capabilities can be seen in these figures. They are the subject of another paper currently in progress.

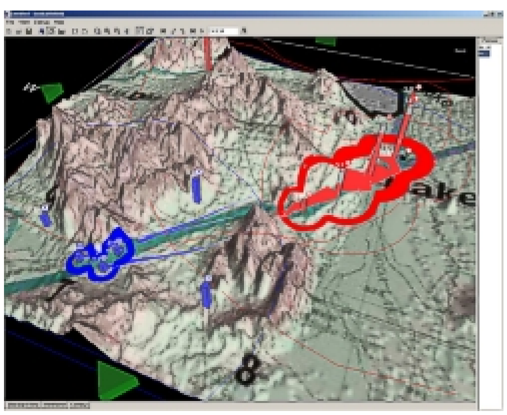

Figure 4- Asymmetrical Perimeters

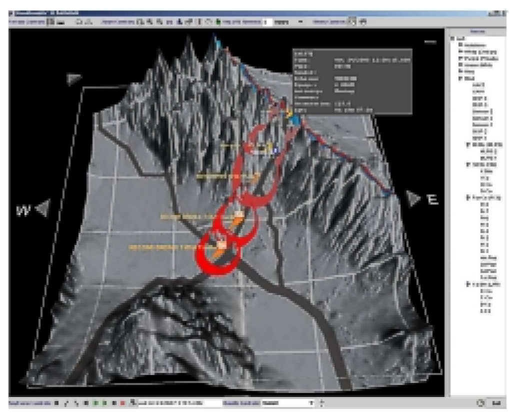

Figure 5 – Fading Over Time

Tailorable Blobs

As experience was gained with subjects and trials, it became apparent that a range of factors or dimensions may, or may not be, important and that blobs need to be tailorable to the situation and to the commander. Many relevant dimensions were identified, as shown in Table 2, and a number of blob treatments were devised to show these factors. Dialog controls were implemented to allow the commander to interactively tune the blob representation to suit the situation. Almost any dimension could be mapped to any treatment as shown in Figure 6. An important issue for complex attribute-representation mapping is transparency. It is critical to make visible what factors contributed to the blob representation and how they contributed in order for the user to have confidence in the display.

Dimensions of Strength	Behavior Treatments
Identity	Uniform Blob Thickness
Reporting Structure	Non-uniform Thickness
Footprint	Dashed Perimeter
Orientation	Sub-Unit Concurrent Blobs
Density	Filled / Transparent / Unfilled
Weapon Systems	Thrust Spikes
Combat Power	Edge Color
Platforms	Blob Color
Range	Color Ramp in One Area
Attrition	Articulated Movement
Intervisibility	Oriented Movement
Fire	*Note: any dimension could be assigned to any treatment.*
Mobility	
Function	

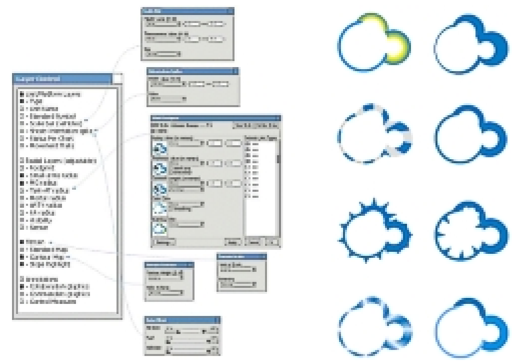

Figure 6 – Dynamic Attribute Mapping

Table 2 – Dimensions of Strength

Quantico Experiment

In the fall of 2000, an experiment was arranged to assess the intuitiveness of the representations and to compare levels of complexity in the representations. About twenty subjects participated at the Marine Corps Base, Quantico, VA. Four scenarios at the company and battalion level were created and each were shown using four treatments animated over time. The treatments were “traditional”, “simple”, “best” and “complex” representations. The simple, best and complex labels reflected our expectations before the experiment. Examples are shown in Figures 7 and 8. The experiment was conducted by EBR Inc. The subjects were given only three minutes to review a scenario with a given treatment. No scenario was repeated for any one subject. Prior to seeing the treatment, the subjects had one minute with a legend. Self explanatory representations should be indicative of improved intuitiveness.

Results showed improvement in situation awareness over the traditional treatment but not as much as LOE1. The treatment that was expected to do the best did indeed provide the greatest improvement but not significantly over the other treatments. One critical issue became apparent during these trials. The terrain resolution and treatment was too coarse to support the subject’s review and assessment of a scenario. Another difference from LOE1 were the greater number of blobs shown. The Quantico treatments used blobs at a platoon echelon. In LOE1, fewer blobs were shown because they were depicted at a higher level echelon. As with LOE1, this experiment also used conventional mechanistic legacy forces.

Figure 7 – “Best” Treatment

Figure 8 – “Complex” Treatment

Entities and Membranes

Much of 2001 was spent in doing a series of refinements and enhancements. Each cycle of design / build / test was followed by decision experiments with feedback from a small number of subject matter experts. A number of significant advancements in blue force representation were achieved.

A fundamental shift in the work occurred when it was assumed that future systems would provide individual entity level data including attributes such as real-time position, orientation and status. This allowed a change in the blob representation from the previous composite circular form as shown in Figure 9. This circular form was a computed inference based on a number of factors including terrain and a platoon’s or company’s single reported position. The new blob form, as shown in Figure 10, is based on multiple entity positions and a membrane enclosure shape with a variable viscosity.

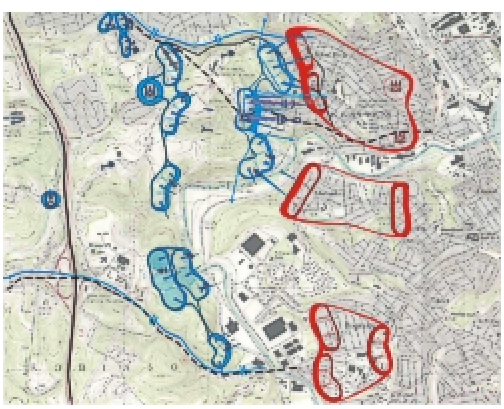

Figure 9 - Composite Blob Structure

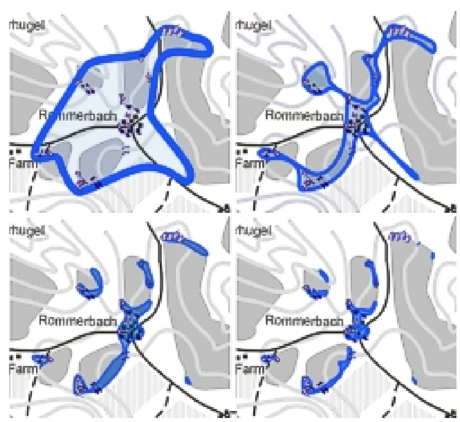

Figure 10 – Entity Blob Structure

Figures 11 and 12 show implementation of the entity / membrane blob version. Significant improvements for a number of additional attributes and representations, including terrain, were also made, and are the subject of other papers.

User operated controls allow flexibility in the representations and how sets of representations work together. The representations need to support very different tasks such as 1) exploratory analysis, 2) fast cognition for real time decision making, and 3) communication of complex issues.

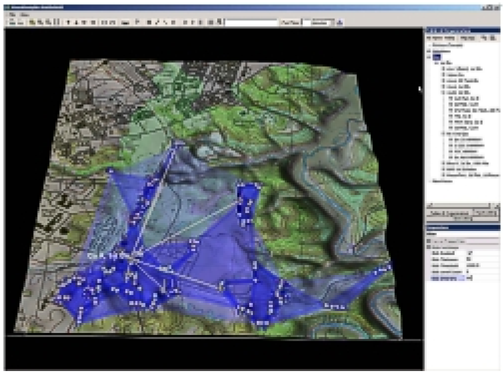

Figure 11a – Company Example with Membrane

Figure 11b – Company Example without Membrane

Entity level representations were developed and tested at the company and battalion tactical level. It was observed that with fewer entities on the screen and at smaller map scales, entities without the membrane are sufficient. As the number of entities on the screen increases, the membrane blobs may become more useful. One of the next steps is to test and refine the representations for scenarios at a brigade and division level.

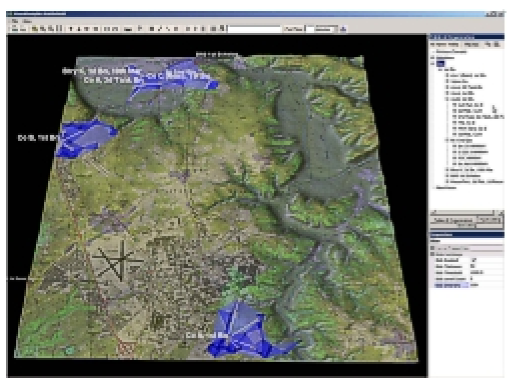

Figure 12 – Battalion Example with Membrane

Entity based representations proved to have stronger spatial qualities as they are based upon actual locations or the footprint (i.e. space actually occupied). They form a foundation for depicting the "see-shoot-sense" properties of forces. Configuration (i.e. location of specific capabilities) and orientation (i.e. where sensors and weapons are primarily directed) can be more clearly shown. Entity based blobs are also tailorable to a number of situations and commanders. Details, and rich combinations of details, are easily accessible and can be selected as required to suit the situation. Additional details can be depicted with a variety of expressive supplementary forms and fused with the entity representations. This is the subject of a forthcoming paper.

Several characteristics of entity based representations are worth emphasizing. The space actually occupied is shown, but more importantly, the space not occupied is clearly shown. The emptiness of the battlefield shows potentials for maneuver. However, most importantly, these representations allow commanders the opportunity to interact with the real data rather than a less expert person's summary or representation. Having an expert algorithm compute a representation would be even more misleading and frustrating for the commander. Entity representations support the basis for decision making by experts by providing the details that allow experts to draw upon their experience and recognize patterns quickly and effectively.

Conclusion

The right visual artifacts have profound effects on people's abilities to explore large amounts of data, assimilate information, to reason with it, to understand it, and to create new knowledge. For commanders, the benefits and their consequences are significant:

- Increased speed of comprehension;
- Improved quality of command decisions;
- Increased tempo of operations;
- Improved command decision making by less experienced commanders and/or under circumstances of great fatigue;
- Use of smaller more mobile command structures; and
- Increased communication and collaboration during planning and execution.

To achieve these objectives, new information visualization representations have been invented of voluminous, complex, abstract information.

Decision experiments and feedback from SMEs indicate that entity based blobs for blue forces increased visibility into an order of magnitude more data without display clutter. More data is managed, and more data is used to advantage, without overwhelming the commander. Entity based blobs enhance perception and pattern recognition allowing the commander to estimate the properties of a situation more quickly and with less training then traditional methods.

A break-through came with a fundamental shift from a top-down representation of aggregations to a bottom-up, entity based representation of individual capability. This allowed experts the opportunity to interact with the real data and not the blurred interpretation of a less expert person or algorithm.

As Brig. General Holcomb, USMC (Ret.) notes, commanders command in spite of the display graphics used to depict the current situation. "The graphics lie to us. The entity based blobs reflect a reality of combat that includes empty space, clustering and form of movement. For the first time, I am looking at something that reflects the reality of my experience."

Acknowledgements

During the course of the CPOF program, the authors have had the privilege of working with a number of senior military personnel who have guided our work and who have actively participated in the progress that has been made. We wish to acknowledge, in alphabetical order, the following:

General Paul F. Gorman, U.S. Army (Ret.)
Brigadier General Keith Holcomb, USMC (Ret.)
Lt. General Paul K. Van Riper, USMC (Ret.)
Major John Schmitt, USMC (Ret.)

Good information visualizations ease cognitive burdens and make explicit the inherent structures used by experienced practitioners to think about complex situations and tasks. It is not possible to create a good visualization without a deep collaboration with knowledgeable practitioners.

The authors wish to thank Ward Page, the CPOF program manager, and DARPA for their continued support and encouragement.

References

Card, Stuart, Jock MacKinley and Ben Shneiderman, Readings in Information Visualization, Morgan Kaufman, 1999.

FM 101-5-1, Operational Terms and Graphics, HQ, Dept of the Army, 1997.

Ferren, Bran, Modern Fictions – How Two Big Wrong Ideas Are Blurring the Vision of Battlefield Visualization, Working Paper, 1999.

Gibson, J.J., The Ecological Approach to Visual Perception, Paperback Edn, Lawrence Erlbaum Assoc; 1987.

Klein, Gary, Sources of Power – How People Make Decisions, MIT Press, 1998.

Schmitt, John, Mastering Tactics – A Tactical Decision Game Workbook, Marine Corps Association, Quantico, VA, 1994.

Tufte, Edward, Envisioning Information, Graphics Press, 1990.

Tufte, Edward, Visual Display of Quantitative Information, Graphics Press, 1983.

Ware, Colin, Information Visualization – Perception for Design, Academic Press, 2000.