# Automated Dynamic Symbology for Visualization of High Level Fusion

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**Abstract** – *Symbols play an important role in identifying informative objects and are widely used in geo-spatial decision support systems and applications. In high level fusion applications, however, simply placing symbols often lead to information overload problem; symbols quickly grow fast in many applications, such as the post disaster monitoring system we are interested in. This leads to cluttered and overlapped icons. With today's advanced technologies, new visual effects can lead to better visualization systems where iconic overload may be perceived as a problem. Therefore, conventional method of storage-indexing-retrieval of large sets of prepared icon images is not flexible enough for the visualization of higher fusion levels. Instead, we propose a dynamic symbology, which automatically generates symbols from parameterized components in a three-dimensional space. The extension to tactical graphics can provide better situation awareness from simplified and abstract visualization. We also report on-going efforts on the prototype of a real-time immersive VR.*

**Keywords:** Symbology, information fusion, situation awareness, tactical symbol, visualization, virtual reality.

## 1 Introduction

A symbology refers to the methodology of symbolic representations and interpretations, or it can simply mean established symbol sets for a specific use. Although the fundamental research has long been implemented in psychological fields, it has been actively studied and developed by military laboratories since the 1970s, when the automated data processing (ADP) systems were widely introduced to applications. Symbology studies can be grouped into three categories as shown in Fig. 1.

### 1.1 Symbology

#### *1.1.1 Symbol Design*

The early symbology focused on evaluating human's visual preferences for graphical attributes of conventional military symbol sets [1], such as size, shape, color and text [2, 3]. For instance some experimental results showed that shape and color were superior to numerals for affecting hostility perception and shape was preferred more often than color, though the difference was small [4]. Human intrinsic and cultural backgrounds were also considered and evaluated in an investigation of natural associations between graphic symbology and concepts [5].

Evolving display technology has produced various types of symbols (Fig. 2). Better displays, in the form of vector graphics and cathode ray tube (CRT), led to studies on additional visual attributes which utilize the inherent capabilities of the new display systems. That is, developing technology provided not only attractive and detailed displays, but also led to better visual factors that helped in effective visual cognition. For example, in the 1970s, researchers had to consider the jaggedness of icon outline due to the large pixels of CRT (Fig. 2 (d)) [3], while a recent research investigated the usability of blurred images drawn on a high resolution display for uncertainty visualization [6].

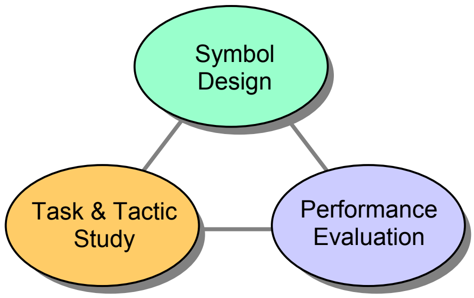


Fig. 1. The studies on symbology

Therefore, rather than specifying all the attributes of symbols and displays, researchers have set up display guide lines to obtain improved symbology based on the visual perception and human factor studies [7, 8].

#### *1.1.2 Task and Tactic Study*

The goal of a task study is to decide what information or activities can be represented by symbols. Task and tactic studies were not actively implemented until researchers realized its importance in the late 1970s. Well-organized goals and tasks were necessary for better abstraction, consistency and communication in symbol design. Early military study was implemented through a survey to experienced soldiers and the result showed that the most wanted tactical information categories are: friendly, enemy, time or capability, status, activities or procedures, terrain or route and planning, listed in the order of importance [9]. Based on extensive survey and with the help of experienced military tacticians, wide range of taxonomy, and the hierarchical structures were also developed [10]. Another advantage of the task and tactic study was the easy communication and work interoperability in joint military actions, such as with North Atlantic Treaty Organization (NATO) or United Nation (UN) peace-keeping forces [11]. The compatibility and interoperability is the one of the main concerns in symbologies today and becomes a requirement to any collaborative tasks [12, 13].

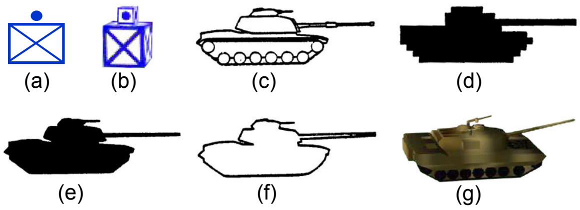


Fig. 2. Various types of symbol:
tactical symbol (a), image mapped on 3D cubes (b), detailed icon (c), blocked outline for larger pixel CRT (d), filled silhouette (e), outlined silhouette (f), and detailed 3D model (g)

#### *1.1.3 Performance Evaluation*

The main concern of this test is to evaluate a user's awareness of situation through a symbol display. To understand human response to symbol display, early military studies categorized five main processes in soldier's symbol use: identification, search, comparison, pattern recognition and integration [3]. The participants were given a set of symbol tablets and were questioned to situation awareness. Based on the statistical results, various symbol types were evaluated. The result suggested that detailed or better looking symbols didn't guarantee better performances because it may draw the viewer's attention to detail in actual display. Therefore in addition to the multivariate situation of a participant's cultural, occupational, educational background, a number of display variables had to be considered. Thus the time-consuming evaluations on designed or proposed symbol sets often discouraged promising improvements.

The present symbology development focuses more on flexibility in symbol generation and display. In the military case, past efforts on symbology were integrated in latest military war-fighting symbology standard MIL-STD-2525B [14].

### 1.2 Recent Applications

In fusion communities, there have been various approaches on symbology in recent applications. University of Buffalo's holistic battlefield visualization with *RAPTOR* [15] takes advantages of pre-processed blurred symbol images in uncertainty visualization. The result suggested the possibility of various visual, auditory and haptic (feel of force) sensation in situation awareness. *STARLIGHT* [16] of the Pacific Northwest National Laboratory provides information transition to a user, retaining context of intelligence data in three-dimensional space. *DRAGON* [17] system of the Naval Research Laboratory utilizes interactive battlefield, to simulate and manage battlefield information. University of Arizona *ATACKS*' visualization [18] is an opposite of realistic battlefield symbology, furnishing an abstract and highly semantic user interfaces. *Data Deja View* [19] is the expansion of the ESRI ArcView symbology for statistical information display using layers of circular boundaries. Researchers at the Air Force Laboratory have studied symbology on workload and situation awareness in a head-up cockpit display using synthetic image of terrain and symbols [20]. Researchers at Kent State University have carried out a comprehensive survey of the existing symbol sets for emergency and hazards mapping and have suggested new symbol images (each symbol in three different sizes) [21].

### 1.3 Issues and Difficulties

Even with the well-established standards and advances in display, the present systems do not provide very flexible software architecture to determine user preferences. Firstly, many organizations still produce such a large number of symbol images that developers face time-consuming indexing works. This is also true in high-end battlefield visualizations, which use indexed image files for texture map to represent detailed 3D icons. There also exist so many visual factors in each and every symbol, tedious image processing have to be carried out to study human factors. Secondly, because pre-indexed symbol set can only represent discreet parameter values, one cannot achieve smooth or seamless visual transition in a symbol image. Lastly, because conventional symbology assumes ordinary 2D documents, common 3D view transformations result in disorientated symbols.

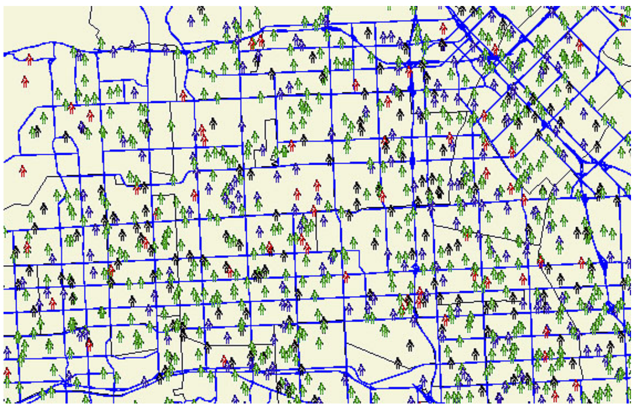

Fig. 3. Adverse effects in visualization of fusion-level 1: Cluttering and overlapping of casualty symbols, (CMIF post-earthquake simulation for Northridge, CA)

In addition, limitations of conventional symbology are often found in a data intensive display, such as post-disaster visualization. Most informative objects can be identified with simple placements of symbols for the lower level of object identification (Level 0 & 1) [24]. However, in higher fusion level of threat assessment

(Level 2 & 3), decision support/making systems usually outputs so much information, that simple placement of symbols causes cognitive problems; a user could be overwhelmed with too many different symbols (Fig. 3). Also, currently there is no standardized symbology for hadzard mapping or emergency management for higher level fusion tasks.

In the present work, we propose a dynamic symbology that synthesizes icon images and symbol components. Instead of conventional method of storing-indexing-retrieving a large number of symbol sets, our system automates the parametric symbol generation for various symbol sets. Eventually, the parameters will be connected to fused outputs and user preferences will be seamlessly captured for both 2D tactical display, and 3D virtual environments.

## 2 A Symbology for Higher Fusion Level

Recent advances in symbology provide not only visual images, but also task planning and situation management functions, called *tactical symbology*. A tactical symbology can be categorized into two groups: *tactical symbols* and *tactical graphics* [14] (Fig. 4).


Fig. 4. Tactical symbols (left) and tactical graphics

### 2.1 Tactical Symbols

Tactical symbols are objects that present information that can be pinpointed to one location at a particular point in time. The main role of tactical symbols is to show the identifications and locations of informative objects in a particular time. Unlike conventional method of retrieving indexed image files, the dynamic symbology controls all the components of a symbol. The main components of a symbol are *frame, fill, numeric, icon, text and graphic modifier*, as shown in Fig. 5.

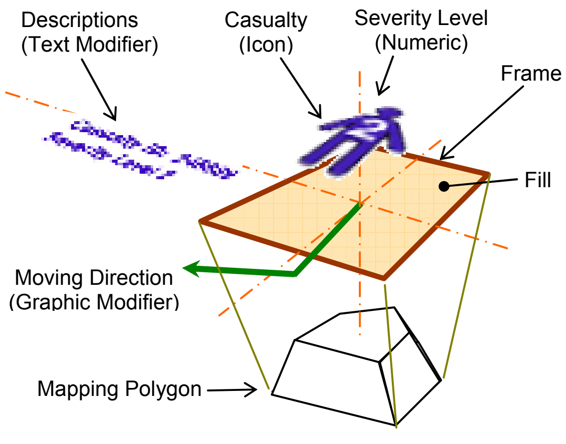


Fig. 5. Components of a tactical symbol

Mapping polygon is the base geometry on which the icon image is mapped, and can be extended to represent detailed objects in three-dimensional space.

### 2.2 Tactical Graphics

Tactical graphics are graphic objects that are necessary for planning and management. Fig. 6 shows the components of a tactical graphics for isolation task.

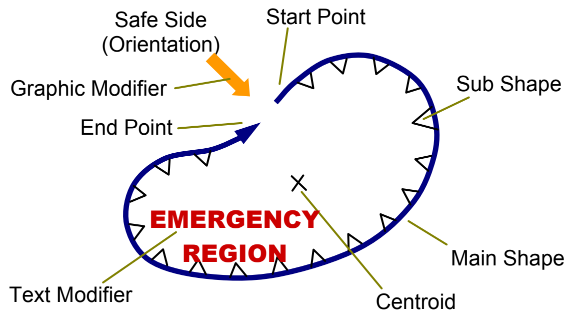


Fig. 6. Components of a tactical graphics
(Example of isolation task)

Although the detailed images and descriptions of tactical symbols, tactical graphics often produce better results in situation understanding, especially for experienced users [22]. Because tactical graphics was elicited from task and tactic study, its integrative and goal-oriented characteristics are more suitable to higher fusion levels that require information aggregation for situation awareness (SA) [23, 24]. Thus the automation of tactical graphics can contribute to an improvement in SA. The parameters of tactical symbols and graphics can be obtained as an output of a fusion algorithm (Fig. 7).

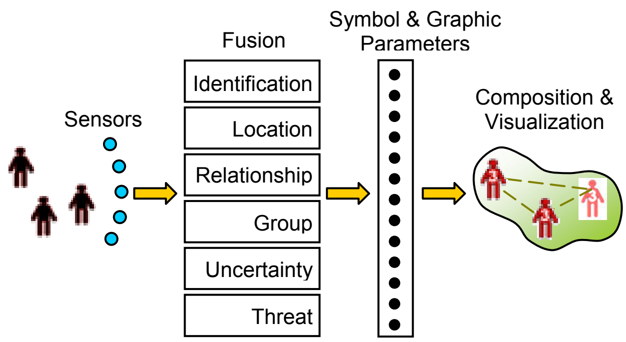


Fig. 7. A dynamic symbology for situation awareness

The seamless display of higher fusion level can also help in SA. LeGare describes it this way: "A seamless transition from a digital C2 (Command and Control) system screen to gaining contact with the enemy – with no surprise in between – is the truest indicator of situation dominance" [25]. However, most applications, such as digital tactical maps or battle field visualizations, usually have no relationship between tactical symbols and tactical graphics. Hence the design of dynamic symbology involves interaction between two symbol categories to obtain smooth transition. When connected to fusion outputs, it will display seamless transitions that give a user both detail identity and aggregated information. For example, cluttered casualty symbols in our hazard fusion map can be grouped and represented as areas of severity levels (Fig. 8).


Fig. 8. A seamless transition from tactical symbols (left most) to tactical graphics

## 3 Automated Symbol Generation

### 3.1 Software Architecture

The dynamic symbology was designed for three-dimensional applications and was built by platform-independent software, using C/C++ and OpenGL [26], so that it retains interoperability between different operating systems. It utilizes DevIL (Developer's Image Library) [27] for the internal image processing and can be adapted to CAVELib™ [28] for the virtual environment (VE) simulation as shown in Fig. 9.

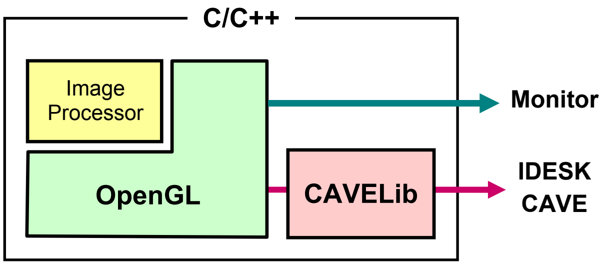


Fig. 9. The software architecture

### 3.2 Symbol Generation

The main procedures of the dynamic symbology are image processing and OpenGL graphics. Instead of the conventional method of sequencing a large number of pre-processed images, the dynamic symbology uses only one iconic image. Once the original iconic image is processed, the internal image processor algorithm generates the required icons with various visual effects, such as transparency, blurs and sharpness (Fig. 10). These effects are used for conveying symbols, which are more powerful in terms of its ability to represent situation awareness [15]. Because the symbol components are parameterized, visualization can simulate both discrete and continuously varying visual attributes. Also since no image retrieval from hard disks is performed, it can help real-time simulations, which require high frame rates.

Most OpenGL procedures consist of building graphics entities from symbol parameters. The common graphics entities are point, line, area and volume. Symbol components, such as frame, fill and graphic modifiers can be generated from these fundamental graphic entities using OpenGL display lists. A display list is a set of batched function calls for immediate or later use. Thus all geometrical shape can be defined using parameters and stored in a display list. Using batched commands in display lists, text or numeric can be generated with either lines or bitmap processing.

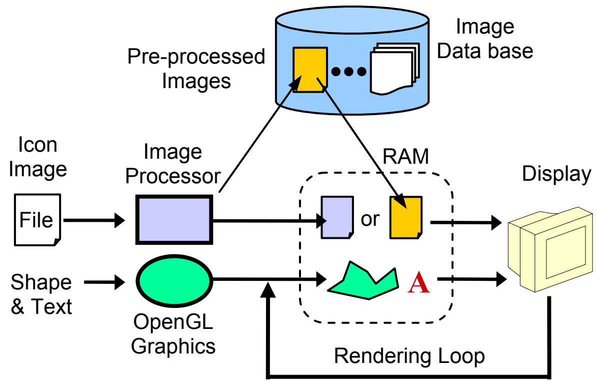


Fig. 10. The procedure of dynamic symbol generation

### 3.3 Class Structure

In our implementation of the dynamic symbology, we have used three fundamental class types: image, bitmap text and geometry (Fig. 11). The image class deals with image processing works, such as blurring, sharpening and transparency. The geometry consists of basic classes for most graphics elements, which are built with OpenGL display list. From these basic classes, one can define any geometrical shapes in three-dimensional space. A string text can be built by either line text or bitmap text. Bitmap text uses pre-defined bitmaps for each character and shape hence has better appearance than line text.

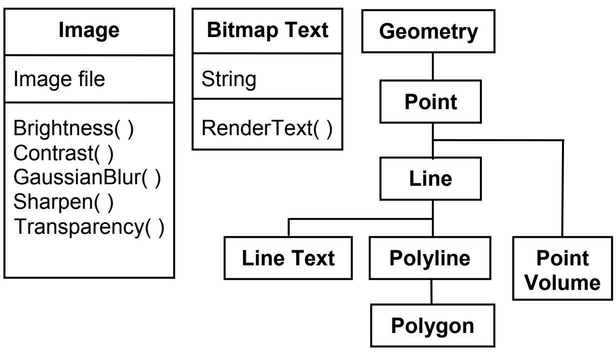


Fig. 11. The fundamental classes for symbol components

The classes of tactical symbols and tactical graphics utilize these fundamental classes for their attributes. For example, a tactical symbol for casualty in Fig.5 has its components, such as the icon (image), severity level (text), frame and fill (polygon), description (text), moving direction (polyline) and mapping object (polygon). Point volume is for a set of irregular points (point clouds) which can be used for scattered objects, for example visualization of area of chemical spill or gas plume. Tactical graphics usually need more extensive use of OpenGL geometries due to irregular and complex shapes.

# 4 Visualization

## 4.1 Symbol Generation

Present research investigates usability of various visual effects available with advanced display devices. For instance, blurred icons can be used for uncertainty visualization [6]. Traditionally blurred symbol icons of this nature are image processed in Adobe Photoshop or a similar image editing software. This is a very time consuming process. In the current work the symbology is dynamically created (no offline editing of image is required), thus making this a much more efficient method for creating blurred symbols. To demonstrate this advantage, a set of blurred tactical symbols was generated to show its usability for uncertainty visualization. Fig. 12 demonstrates the use of blurred icons for uncertainty visualization. The icons were generated with Gaussian blurring to simulate uncertain casualties. The one at the center is for 100% certain casualty and the rest are blurred depending on the radial distance from the center.

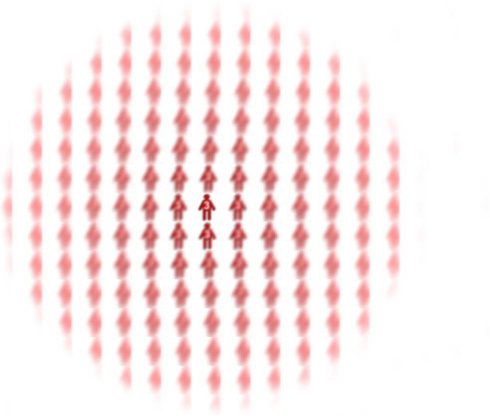

Fig. 12. Visualization of uncertainty with blurred icons. This dynamic symbology was simulated by a linear radial distance parameter as blurring factor. One hundred levels of icons were generated at run-time from just one JPG icon image file.

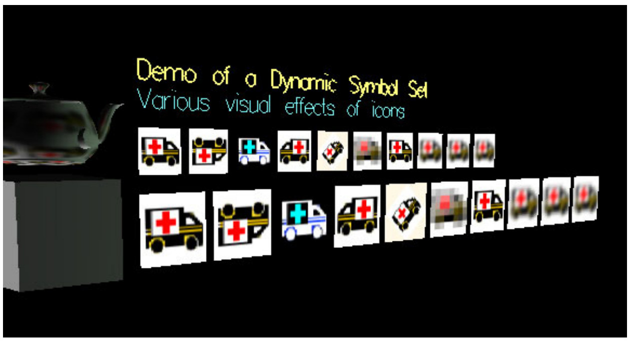


Fig. 13. Various sizes and visual effects of 3D icons generated at run-time from a single image file

Many other visual effects were also demonstrated using the automated symbol system. Fig. 13 shows ambulance symbols which were generated from one iconic image and Fig. 14 illustrates an example of tactical graphics in a three dimensional space.

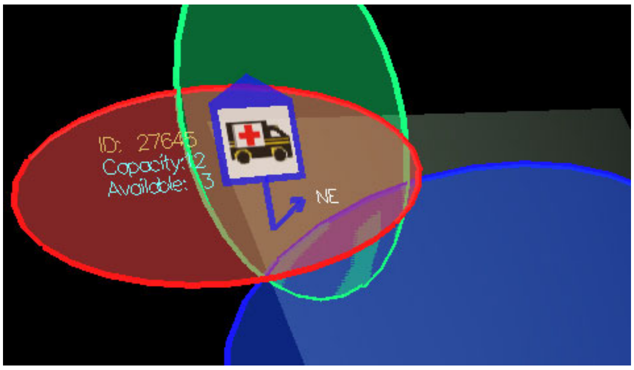


Fig. 14. A simple informative ambulance symbol and tactical groups generated by the dynamic symbology system

## 4.2 Earthquake Response Symbology

A prototype is being developed in our earthquake response system to demonstrate the usability of the dynamic symbology. For various elements of post-earthquake situation, the symbology prototype captures both detail descriptions for identification and abstract information for situation awareness. Some of these elements are geo-referenced traffic information, tactical symbols representing locations and identifications of casualties with uncertainty grades, and tactical graphics, with elements such as groups of casualties, ambulance routes, police tracks with observation ranges and clouds of points for hazardous material. Some of these elements are shown in Fig. 15.


Fig. 15. A prototype scene for monitoring post-earthquake situation

## 4.3 3D Visualization for Virtual Reality Application

The software for the dynamic symbology was made for three-dimensional applications with OpenGL. Unlike static icon image texture-mapped on polygon models in most battlefield simulations, one can have three-dimensional tactical symbols with dynamically processed images at run-time. In addition to the multivariate condition of symbolic representation, several human factors issues, such as visual, auditory and haptics [15] have to be studied to understand its effectiveness. An effective means for visualization is to utilize immersive display and virtual reality (VR) interfaces [29, 30].

Our 3-D dynamic symbology has been integrated with VR based interface. A prototype is being tested on ImmersaDesk™, an immersive display system. In this system a user can wear stereo glasses and perform flythrough of a terrain map and use the dynamic 3D icons to represent fusion and other results.

## 5 Conclusion and Future Work

A visualization system for a high level fusion demands a flexible and visually compelling symbology. As a component of the human-centered visual system for post-disaster fusion, we have developed a new dynamic symbology system to help higher level fusion analysis task that concerns situation awareness and threat assessment. The dynamic symbology is capable of composing the elements of symbols and automatically generating visual effects at run-time. Its tactical graphics can further contribute to better performance in situation awareness. Our system is platform-independent and works on both PC and UNIX based systems. It is capable of generating both 2D and 3D symbology, hence it can be expanded easily to advanced VR applications in the future. The future research will be focused on developing effective tactical graphics for a more refined and aggregated fusion visualization. We also plan to perform human factor study to evaluate the effectiveness of the dynamic symbology concept.

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