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Retrieval of Hidden Data -- the Flip Side of Decluttering

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Retrieval of Hidden Data -- the Flip Side of Decluttering

ABSTRACT

One of the major problems facing decision makers today is a proliferation of data from a multitude of sources. Many techniques have been proposed for de-cluttering displays. The key idea is to show only the relevant data at the proper time, avoiding the visual distraction of other non-pertinent data. Many of the techniques deal with clustering or organizing the information at higher levels of abstraction. Sometimes through, the details **are** important. The challenge is to provide access to these lower level data sources from within the visual context of simplified higher level data. In this paper we develop several techniques providing efficient access to detailed information, and timely triggers to help the user know when, where, and how to access this information.

INTRODUCTION

Advances in technology have given rise to environments brimming with information. From 24-hour news stations to streaming video, there is now far too much content available for any single person to have enough time to process it all. While this problem of information overload [LAM04] may cause average consumers of information some frustration in terms of determining what program to watch, or what blog to read, in the Command and Control (C2) community the consequences of inadequately processing available information are often dire.

Conversely, having too little information is one of the causes of uncertainty. In a Command & Control, Communications, Computers, and Intelligence (C4I) environment, decisions must often be made under uncertain conditions. Unfortunately, one of the common “solutions” to uncertainty is to generate copious additional data in the form of probability ranges etc., which must then be managed. If the addition of information is not pertinent, it increases the level of “noise” which the human operator must cognitively process. This additional information may reduce ambiguities, but does not necessarily help the decision maker develop a superior decision. It is therefore imperative to display salient and sufficient information for the specific operating scenario.

Lack of information, an overload of information, conflicting information, and misinterpretations of information are collectively referred to as ‘fog of war’, and overcoming this fog to make better decisions is a goal of improving the level of situational awareness [ARMY03].

De-cluttering (or clutter reduction) and interactive control are two techniques for managing large quantities of data. When clutter reduction is performed programmatically, care must be taken to make the user aware that certain information is being hidden for the sake of clarity. Interactive control then becomes an important aid, ensuring that the user can retrieve that information on demand. Such control typically is accessible to the user through user interface constructs such as buttons, menus, and sliders.

De-cluttering and interactive control work by hiding the underlying details used to create the higher level information. This can increase the chance that the data will be misinterpreted, so care must be made to ensure that only extraneous details are removed. More specifically, attempts to reduce fog of war caused by too much information can increase fog of war due to misinterpretation of information.

In this paper we focus on balancing too much and too little information, by providing access to underlying details within the context of other consolidated, higher level data.

Application Focus

In an ideal world, the decision maker would have the data needed, at the right level of detail, within the proper context, presented in the best possible way, exactly when needed to make a decision, but would never have to deal with extraneous information. This is not possible with current understanding and technology, but is the goal towards which we should work.
Time sensitive targeting provides an illustrative example of these tasks in a complex C2 decision making task. Each decision made while successfully engaging a fleeting target is a unique sequence of decisions, and each requires a specific set of data. Ideally, during each portion of the decision sequence, only data pertinent to that specific decision would be displayed, with other data, extraneous to the current decision, filtered out of the display. This ensures the decision maker has the appropriate information at the appropriate level of detail to make informed decision at every on step of the process, and is not distracted by peripheral data.
C2 information displays frequently provide a mix of 2D and 3D visual data, along with text and possibly audio within the same application. This is a reasonable approach, as various studies have shown that 2D display is better suited for certain tasks while 3D is better for others [SMA02]. Traditional battlespace simulations have focused on the 2D display of data. 3D data displays are particularly suited for urban combat environments. Audio is often integrated into such systems (with various levels information), but battle field conditions may sometimes preclude its use. This necessitates visual alternatives for all audio options. Our paper will consider 2D, 3D, temporal non-visual data, and audio data being presented to an end user, and how to manage information overloading that each form of data produces.

Implemented Examples

We examine techniques for accessing data details which were previously hidden, within the context of an existing de-cluttered computer generated simulation environments. Our experience is based on developing a series of 2D (MÄK PVD) and 3D (MÄK StealthXR) visualization toolkits and trainers (BC2010, MAGTF and QuickStrike), all aimed at the military audience. We believe these findings transfer to any C2 oriented display, but need to run experiments to be more definitive.

Our system requirements are based on feedback from fielded systems, customers (both foreign and domestic) who purchase the base toolkits in order to build their own systems, and employees with military experience. Some of the fielded system locations include: Fort Leavenworth Command and General Staff College; Fort Lee (logistics course); USMA (West Point); U.S. National Guard 35 Field Training Group; Illinois National Guard; USME Expeditionary Warfare School in Quantico, UA

CLUTTER

What is Clutter?

Clutter is often thought of as the state of having too many objects, leading to a confused or disorganized state. For example, in Automatic Target Recognition applications, any objects in the field of view that are not targets, but may act as “confusers”, are referred to as clutter (e.g. tank-shaped bushes)]. In this paper, we are concerned with computer-generated clutter (whether visual or aural), that may interfere with effective decision making in a military context.

Edward Tufte provides insights into the nature of clutter [TUF83, TUF90], describing it as the things that cause confusion in a visual display. However, Tufte also points out that it isn't simply large amounts of data that cause clutter, but rather that flaws in the design of the information display are the cause of the confusion. Tufte provides us with several sources of clutter, including "chartjunk", which refers to visual elements of a display that don't actually provide information and in fact often obscure relevant data.

Reducing large amounts of data into more manageable chunks to facilitate understanding is one of the stated goals of the field of scientific visualization [ALE06]. There have been many field studies demonstrating that reducing the amount of information available to users of information systems can greatly improve user performance [PHI82, TUL88]. Similarly, there are a wide range of techniques available for reducing visual information, such as filtering [AHL, STO] and magnification [FUR86].

Rosenholtz [ROS05] takes this a step further, focusing more on this confusion-causing aspect, and offers this formal definition: "Clutter is the state in which excess items, or their representation or organization, lead to a degradation of performance at some task."

Clutter Reduction Techniques

There are two main techniques for removing clutter from a display: *data elimination* and *data consolidation*. *Data elimination* employs user-controllable filters [STO95] to remove chosen items of information for a display. In the case of a realistic display, this could include various effects such as smoke, fire, vapor tails, etc. *Data consolidation* combines entities with similar attributes into a single higher-level representation.

For clarity, we start with a simple example. Two tanks can be combined to form a section, two sections to form a platoon, three platoons to make a company, etc. This process, called dynamic aggregation, can happen automatically when like entities overlap from the perspective of the viewer, thus helping to reduce the problems associated with occlusion. These techniques have been described in detail in [SUM05]. From a data detail perspective, what happened? The relevant data was deemed to be object type (tanks), approximate location, and quantity (one Company). The irrelevant data (which if present would constitute clutter), was deemed to be the realistic visual object aspects, exact geo-spatial location, past geo-spatial locations (history trails), position in hierarchy, armament, strength etc. While there are certainly times that these details are important, they don't necessarily need to be seen all the time for all objects. Additionally, we should consider if displaying these details should be activated manually or should happen automatically.

Problems Caused by Clutter Reduction

Clearly, any degradation of performance is something to be avoided in C2 situations, where effective decision-making can literally mean the difference between life and death. While removing visual clutter addresses one problem, care must be taken that we do not cause the opposite problem: inadequate **relevant** information to make the necessary decisions. Too little information can cause as much confusion or degradation of task performance as too much detail. The balance between too much and too little detail is critical.

Interactive Control

Interactive control is considered of vital importance in information visualization. Visualizing data can be viewed as an explorative process, providing the user with control over when, where, and now data is presented is what makes the exploration possible. Additionally, what one user considers a cluttered display, another many not. It is this interaction that allows the decision maker to identify and isolate the data relevant to his or her current decision.

Wehrend [WEH90] describes a set of visualization tasks, including such operations as Locate, Distinguish, Cluster, Compare, and Correlate, all of which require the user to have some control over data presentation.

Shneiderman [SHN04] expands these tasks into a full task taxonomy, driven by a visual-information seeking mantra: overview first, zoom and filter, then details on demand. The task order is a logical one, where a user first gains an overview of the entire set of data, then begins to zoom in on interesting items while filtering out the uninteresting ones, and finally displaying additional details on the selected items. Additional tasks on selected items include viewing relationships with other items and extracting the items for later analysis.

IN-CONTEXT DATA RETRIEVAL TECHNIQUES

Visualization of 2D and 3D data sets each provide their own unique challenges, and visualizing higher dimensionality data [LEB90] is even more difficult. For example, the path of a jet through the sky can be viewed as 4D data, where time is the extra dimension. Viewing the paths of all the entities in a large battle over the entire duration of the battle would produce an unintelligible and unmanageable amount of visual clutter.

For two-dimensional tasks, some fairly traditional approaches of filtering and searching are applied. For three-dimensional data, a more novel method involving “exaggerated reality” [SUM05] has been taken, where some aspects of a scene are exaggerated while others are suppressed, thus removing visual clutter and letting the user focus in on the desired data.

Audio has its own challenges for determining what it considered clutter and how to remove it. As soon as a system gets before presenting one stream of audio, problems begin to occur with the user perception of the overlapping sounds [PAP97]. If audio is used to provide information to an end user beyond just what the actual presence of the sound provides (i.e., an alert message), then some level of user-controllable management must occur.

Geo-Spatial Visual Data

The primary *technical* task of our products and trainers is to visually display simulation data being broadcast over a network, in either the DIS or HLA protocols. This data typically represents discrete entities (i.e. tanks, plane, and ships) at certain locations in the world, having attributes such as orientation and damage state. The majority of the screen space of the application’s main window is taken up by the display which shows visual representations of the entities at their corresponding geo-spatial locations. This display will be 3D for the Stealth and StealthXR, and 2D for the PVD and the trainers.

Note, the primary goal of these systems is aid decision superiority, but this paper focuses on the technical aspects.

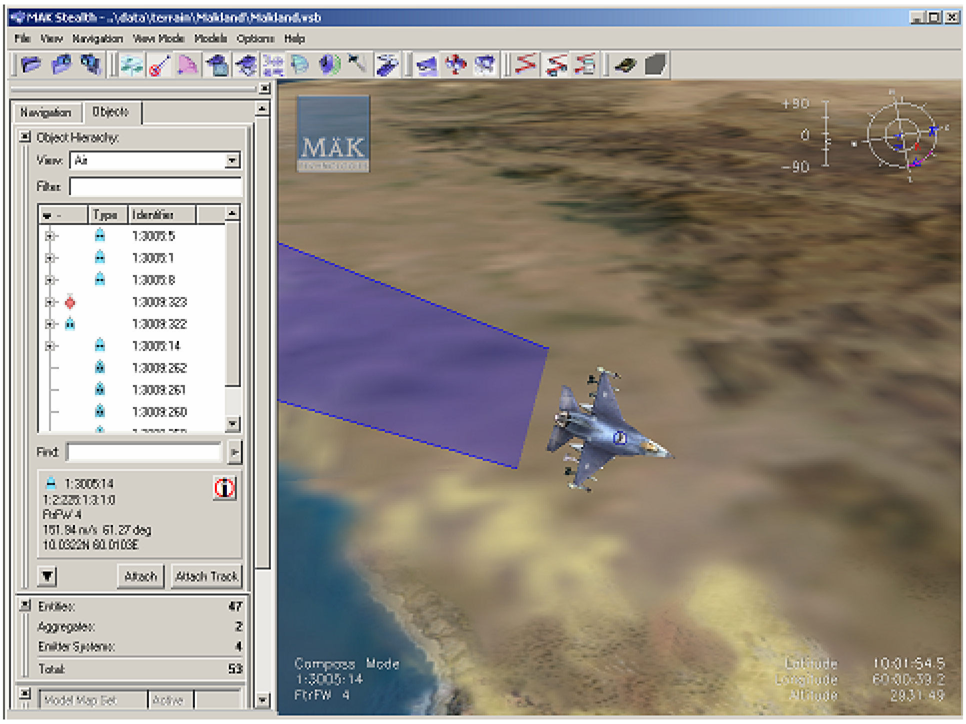

Figure 1 Realistic 3D View

Why Clutter Occurs, and Why it is a Problem

Clutter can occur very rapidly in a 3D view, and in a number of ways. The most obvious way is a large number of entities in the scene, say several thousand. In that case, the application display may become extremely cluttered, causing the user to become confused about, for instance, which armored units are friendly versus unfriendly. Having a large number of entities in a scene can also lead to occlusion, where units at the front of a column are visible, while units to the rear are not. Units may also be occluded by terrain, such as hills or buildings.

A non-visual side effect of having too many entities in the scene is degradation of the frame rate. Frame rate refers to the ability of the computer to render new data quickly on the display screen. Frame rate is particularly important for 3D applications because of the level of interactive experience that modern graphical applications are expected to provide. Even with computing power expanding in accordance with Moore's law [SCH97], attempting to render several thousand entities in a realistic fashion puts a strain on most graphics cards available on the market today. If data is lost or out of date because the system can't keep up, then decisions will be made based on flawed information.

Data Elimination as a De-cluttering Technique

Conceptually, the simplest form of reducing clutter is to make it go away, by either hiding processed data, or not submitting the data to the rendering engine at all. In StealthXR, where a realistic 3D view of a battlespace simulation is presented (see figure 1), filters remove entities beyond our visual range from the display.

In previous implementations, we would naively send all entities to the graphics pipeline and let the underlying display engine decide what objects to render based on being outside of the viewing area. However, a common computer graphics technique called Level of Detail (LOD) management states that objects of 'lesser' importance can be rendered with less fidelity than objects of 'higher' importance [CLA76]. In a 3D environment, this order of importance is generally associated directly with the distance from the object in question to the eye point. As an example, a tank right next to the eye point might be rendered in highly realistic detail, while one a kilometer away might be just a simple shape, and one several kilometers way might just be a few pixels in size.

StealthXR implements the LOD concept by using distance from the model to the eye point to determine the fidelity with which to render a model, but goes a step further by removing the model's geometry from memory once the entity is beyond a certain distance from the viewing point. The distance is configurable by the user at run-time.

An entity beyond the specified visual distance can still be identified by a small circular marker on the 3D display, and maintains an entry in the Object Hierarchy toolbar (see Figure 2). In this way, we reduce visual clutter and improve rendering performance, while still informing the user about the existence of the entity.

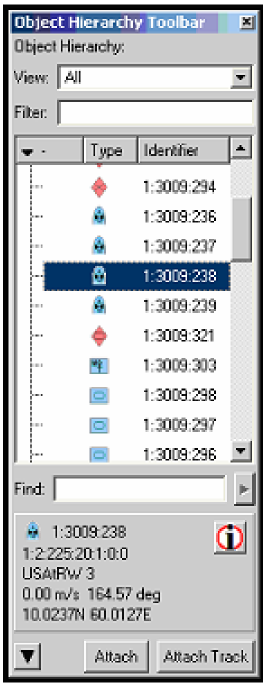

Figure 2 Object Hierarchy Toolbar

The 3D display primarily exists to provide a realistic view of the virtual world modeled within StealthXR, but it also provides additional details about certain entities in a 2D manner. A visual overlay is drawn over the 3D view, in the same manner as laying a transparent acetate sheet over a map. Passive details of the scene are displayed unobtrusively in the corners, such as the latitude, longitude, and heading of the eye point. If an entity is selected, identifying text describing the entity is presented. Further, if the mouse cursor is moved over an entity in the scene, a 2D label appears on the overlay, providing yet more details (figure 3). All aspects of the overlay information can be filtered to reduce screen clutter if the user so desires. Finally, right-clicking on an entity allows the user to bring up an even fuller descriptive dialog box for the entity, containing most of the state information described in the DIS specification (figure 4).

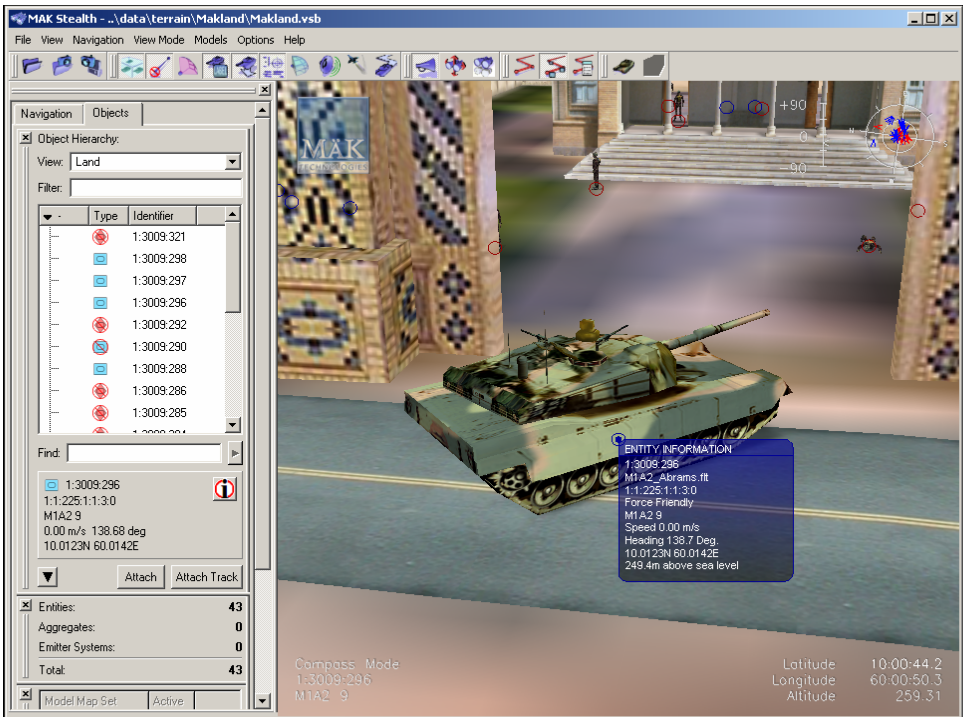

Figure 3 Object details shown on demand

Light weight information is provided by mouse movement over the selected object

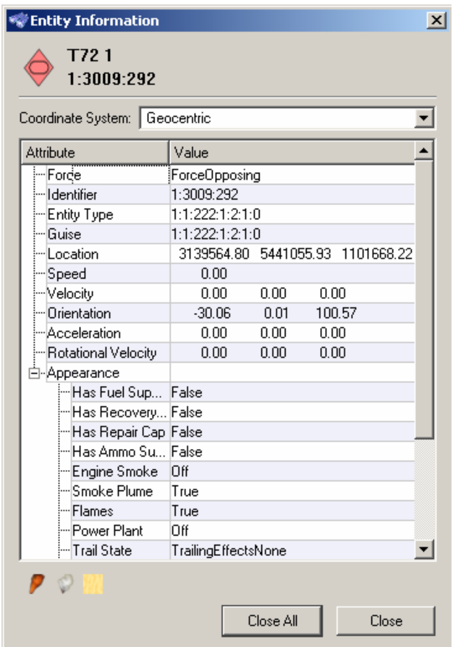

Figure 4 Detailed object information

Detailed object information is provided by right-clicking the mouse button. This takes more user effort than the mouse over version, but is used less often.

Techniques for Supplying Details

Another major task accomplished using StealthXR is to locate a specific entity within the 3D world and view information about the entity. While there are multiple ways to accomplish this task, the two main paths that users take are to navigate through the 3D world and find the entity based on visual clues ("the jet is on the runway at the airport"), or to scan the list of entities in the Object Hierarchy for the list.

In terms of task efficiency, Sebrechts et al. [SEB99] demonstrated that searching a 2D interface for an item is faster than searching a 3D interface, and searching text is even faster than 2D. Thus, the Object Hierarchy presents a 2D list containing a description of all the entities in the 3D world. Each row of the list contains both text describing the entity and the appropriate 2525B icon for the entity type.

To put this in the perspective of Shneiderman's visualization philosophy, "overview first, zoom and filter, then details on demand", the Object Hierarchy provides the user with the capability to zoom in from the initial overview, filtering the data in the list to focus in on the desired entity or entities. At the top of the panel is a dropdown control containing a list of the major entity types (land, air surface, etc) and force designations (friendly, unfriendly, neutral). By selecting from this list, the contents of the list are reduced. Next, a textual filter is provided, where the user can enter arbitrary text, and only the items in the list that match that text will be displayed. In this way, the user can quickly reduce a list of possibly thousands of entities to a more manageable number, even to a single entity. Finally, at the bottom of the list is an expandable panel that shows textual details of any entity in the list that is selected, fulfilling the final task of 'details on demand'. As noted previously, reducing clutter sufficiently to find information is important, but quickly being able to locate additional details when the decision maker requires them is just as important.

An additional aid to searching this list is a "Find" area at the bottom of the panel, into which the user can type arbitrary text. The list will then jump to the first instance in the list that contains that text, with a "Next" arrow to go to matching entities lower in the list. This methodology was chosen because of the similarity to searching in most web browsers, thus providing a paradigm that should be readily apparent to most computer users and not require any training to utilize.

Other examples of data where the details become important are spot reports from units and messages or data from intelligence sources. An icon can be displayed on the screen at the location of the unit reporting or sensor providing the data and protocols can be observed to give visual cues about its timeliness. Specific details can be produced upon demand. The MAGTF training application (figure 5) shows a user requesting intelligence information about various units displayed in the scenario.

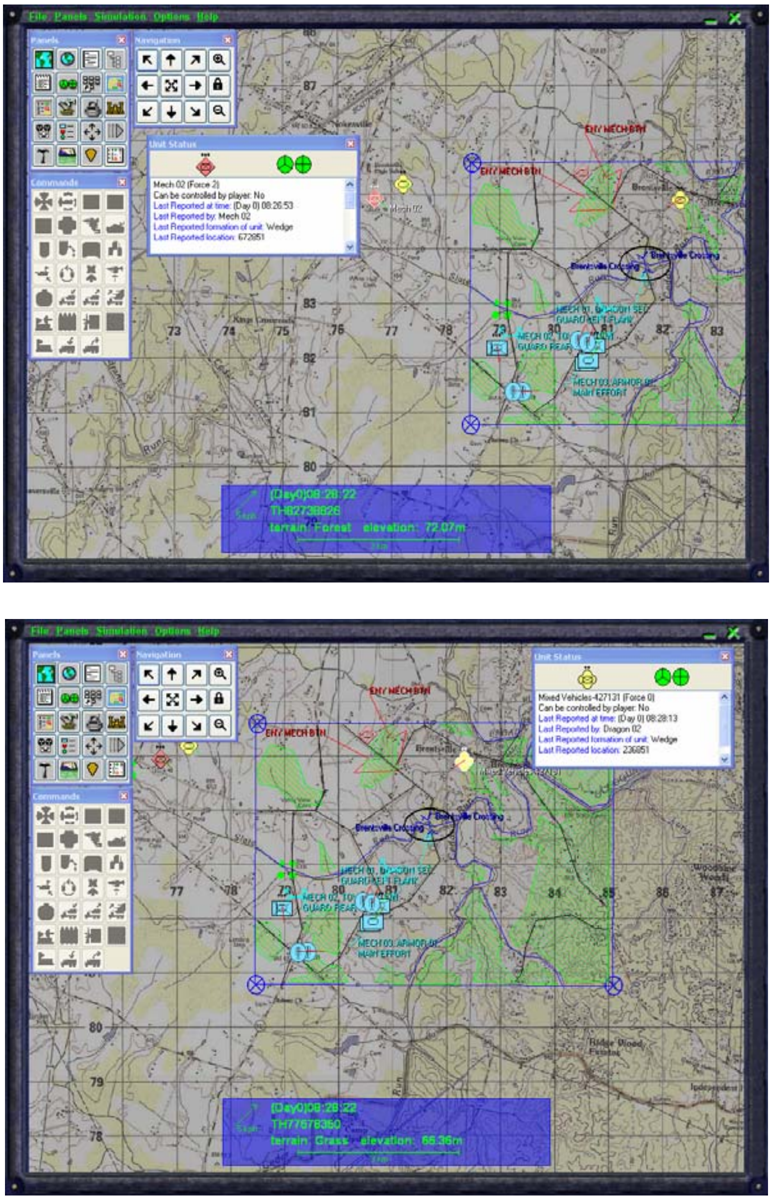

Figure 5 (a, b) Spot Reports

Icons show the results of data fusion from multiple spot reports in MAGTF, a U.S. Marine Corps trainer. Dialog boxes, upon demand, show the more detailed information upon which the icon selection was made. The two images show the icon and associated dialog box for identified and unidentified units respectively

Temporal Non-Visual Data

Some data is predominantly temporal, as opposed to geo-spatial, such as user alerts and messages. During experiments with scripted scenarios in the QuickStrike trainer, we discovered that having messages automatically pop up as they arrive was distracting and very stressful for the user, as the arrival of each new message would replace the one which the user was currently reading. System users may not be able to control the flow of events, but they should be able to control how they view them.

The first simplistic approach is to pop up independent viewers for each event. The user receives each alert, and partially unread messages are not lost. However, the screen quickly fills with panels, and the user loses the sense of sequence or timing

A more complex approach was implemented – a single view panel, with "backlog" management. Each event is added to the queue. New events queue behind the currently viewed event. A red alert banner flashes at the top of the viewer, to indicate a new event has happened. Optionally, an audible alert indicates that events are piling up. A "View Next" button allows the user to control iteration through the backlog of messages. The "View Next" button changes to a non-selectable "No backlog" when all messages have been processed. Older messages can be re-examined through the "Event List Dialog".

This approach conserves reduces screen display clutter and preserves temporal order. But, it doesn't help the user process the information more efficiently than a stack of papers on a desk.

Color coding of salient words in the text messages cues the user to the most relevant data, allowing them to skim the text. The colors chosen correspond to force type colorings used by 2525B symbology, but others could be chosen. Since each decision maker is different, the ability for the display to adapt to the decision maker's process remains very important.

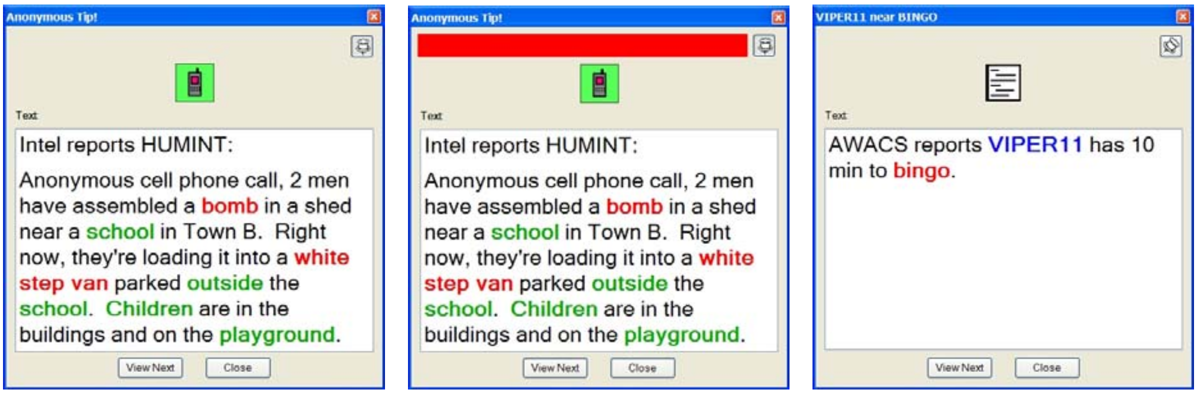

Figure 6(a, b, c) Message Handler

1a: The initial event (alert1) appears in the viewer, with color emphasis on salient information
1b: While the user is absorbing info in alert1, another alert is received by the system. Because the view is "pinned" to alert1, alert2 is queued for later viewing, and the viewer enters a flashing "backlog" state.
1c: If the user does not pin the viewer to alert1, then alert2 will replace alert1 in the viewer, without a backlog warning.

Audio, Video, and Imagery Data

Although text is the most common message medium, images, audio, and video have similar attributes. They are predominantly temporally ordered, although they have a spatial reference.

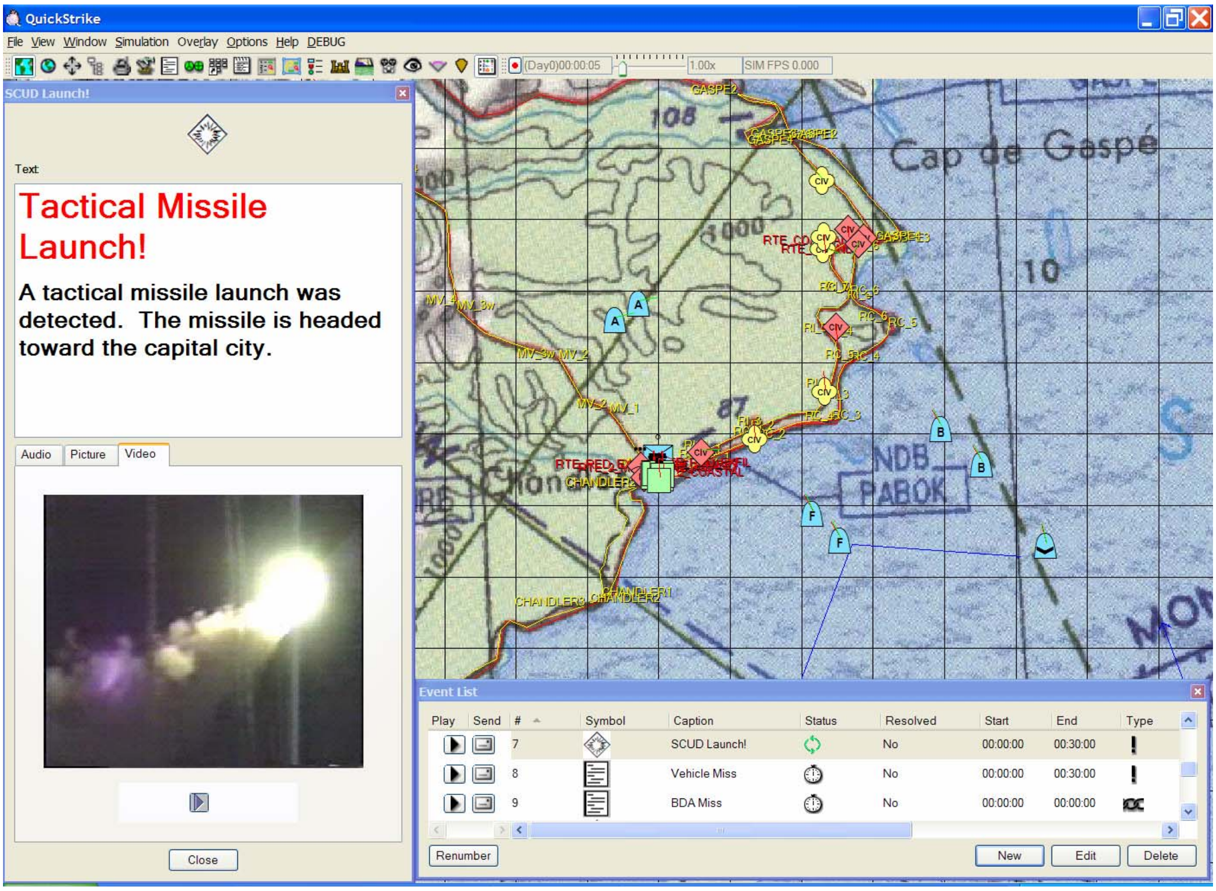

Figure 7 Audio, Video and Image Messages

Similar to the text message organizer described earlier, tactical trainer QuickStrike provides support for audio, image, and video message support.

CONCLUSIONS AND FUTURE WORK

The ability to reduce visual clutter to manageable levels and reducing the ‘fog of war’ effect is important to decision makers now and into the future. We have presented several techniques for effectively accessing pertinent details from within a de-cluttered display. Again we recall Shneiderman’s philosophy of “overview first, filter and zoom, then details on demand.”

This visualization philosophy has been successfully implemented in several of MÄK’s toolkits and trainers. Customer feedback of the system capabilities to date has been largely positive, although it is clear that the products would benefit from more quantitative user studies to fine-tune the performance of certain tasks.

The current visualization techniques for reducing clutter presented in the StealthXR are effective, but by no means comprehensive. The dynamic aggregation concept could be extended to more automatically group entities of like types into squads, platoons, etc based on viewing distance. The current implementation of the dynamic model loading and unloading does not take into consideration the size of the entity, so both a tank and an aircraft carrier would both be unloaded at the same viewing distance.

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AFRL/Mesa -- QuickStrike
PMTRASYS – MAGTF
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APPENDIX

MÄK Technologies has three visualization tools: the MÄK Plan View Display (2D tactical map display), the MÄK Stealth (traditional, realistic 3D viewer), and the MÄK StealthXR (3D viewer which also displays non-realistic data such as MilStd 2525B icons, NCBR (nuclear, chemical, biological, radiological) hazards, satellite imagery, threat domes, etc).

These three visualization products inter-operate and are commercially available and supported on a variety of platforms. All products natively support HLA and DIS, while plug-in APIs can be tailored to import entity locations and tracks from various C4I protocols. All products support a variety of terrain formats, raster maps and vector data. All products have been run on desktops and large screens. To date, only the 2D PVD has been run on a hand-held device, although we see no barriers to supporting 3D on a hand-held

We also draw on the experience of the tactical trainers with a strong visual component:

- **Battle Command 2010.** Trainees assume the role of a Brigade or Battalion commander or staff member to practice conventional land warfare planning and execution skills.
- **MAGTF-XXI.** Trainees assume the role of a Marine Expeditionary Unit (MEU) commander or staff member to train in expeditionary warfare tactics.
- **Army Commander 2010.** Trainees act as a Combat Service Support officer to learn the complex relationship between logistical and operations plans.
- **Quickstrike — TST Trainer**. In this U.S. Air Force Mission Qualification and Mission Rehearsal trainer, trainees practice using a realistic, deployable simulation environment for more effective Time Sensitive Targeting (TST) team training and mission analysis.

More details can be found on the MÄK Technologies web page [MAK07].

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