4D symbology for sensing and simulation

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ABSTRACT

The Army's Common Picture of the Battlefield will produce immense amounts of data associated with tactical goals and options, dynamic operations, unit and troop movement, and general battlefield information. These data will come from sensors (in real-time) and from simulations and must be positioned accurately on high-fidelity 3-D terrain. This paper describes a 4-D symbology (3-D symbols plus time-dependence) for battlefield visualization that addresses these needs. It is associated with the Army's 2-D symbols for operations and tactics so that the information content of this symbolic structure is retained. A hierarchy is developed based on military organization to display this symbology. Using this hierarchy, even complex battlefield scenarios can be displayed and explored in real-time with minimal clutter. The user may also move units around by direct manipulation, define paths, create or delete hierarchical elements, and make other interactions. To strengthen the capacity for distributed simulations and for using sensor information from multiple sources, DIS capability has been integrated with the symbology for dynamic updates of position, direction and speed, and hierarchical structure. The paper will also discuss how the techniques used here can be applied to general (non-military) organizational structures.

KEYWORDS: GIS, 3-D Visualization, Symbology, Virtual Reality, Unit Visualization, Real-time.

1. BACKGROUND AND NEED

The 21st century battlefield will use sensor-dependent systems and require rapid force projection, mobility, and precision strike. Information storage, computing, and networking technologies will be brought together to form a "common picture of the battlefield"--a picture shared by all ranks from infantrymen to overall commanders. The commander will need tools to enhance his ability to visualize the ever-changing battlefield and to engage in a decision-making cycle more rapidly and efficiently than his adversary. The infantryman will need his own, focused battlefield picture that includes rapidly disseminated command information and updates on battle conditions that affect him directly. These technologies should also be employed for detailed, effective planning, both tactical and strategic. Finally, all levels of the military will require careful training in the use of the technologies and the rapid amounts of information that they present. Simulations that may be distributed will play a key role in both planning and training.

The common picture of the battlefield will produce immense amounts of data associated with tactical goals and options, dynamic operations, unit and troop movement, and general battlefield information. A widely held objective is to display, update, and interact with these data in real-time using 3D visualization techniques and accurate terrain models[1]. In this way military personnel can get quick and accurate overviews of the actual combat situation. "Real-time" here implies frame update rates of at least 15 frames per second. This puts a stringent time constraint on the system; all computation, rendering and display for each image must be completed in 1/15 second. All this detail must not overwhelm either the visualization hardware or the user, who must navigate the data in real-time and receive updates instantaneously.

There are many potential non-military uses for the organizational hierarchies created here. For example, the hierarchy of a vast company could be used. A world-wide company with several hundred thousand workers would have a very rich and complex structure. It could be laid out geographically on a map or a globe. One could then navigate the structure using graphical representations and interactive techniques described here. At lower levels one might see activities for individual departments (perhaps updated daily). Lines of authority and communication would also be readily apparent. An organization would not necessarily need a geographical dispersal. The structure could be laid out in 3D space without a geographical meaning. Here spread in a plane could show organizational breadth (e.g., separate divisions would occupy different positions in the plane). Perpendicular distance from the plane might then show depth into each division. A completely different but strongly geographic hierarchy could show wide area network structure. Here Internet nodes might be placed at their appropriate geographic locations on a map and local area networks and subnetworks would be arrayed below the nodes. Point-to-point links would be shown by pipes that could depict (by color mappings, changes in size, etc.) myriads of data about traffic levels and types of traffic.

In this paper we concentrate on the battlefield organization scenario. We have developed a 4D symbology (3D symbols plus time-dependence) for battlefield visualization that addresses these needs. It is associated with the Army's 2-D symbols[2] for operations and tactics so that the information content of this symbolic structure is retained. We have developed a hierarchy based on military organization to display this symbology. Using this hierarchy, even complex battlefield scenarios can be displayed and explored in real-time with minimal clutter. We will discuss this hierarchy and how symbology at various levels can be displayed based on distance to the viewer's eyepoint. Selective queries may also reveal levels of the hierarchy regardless of distance. The user may also move units around by direct manipulation, define paths, create or delete hierarchical elements, and make other interactions. We will show how information about hierarchical content, distribution, and movement can be revealed at all levels of detail.

2. REPRESENTING BATTLEFIELD INFORMATION

The Army and other military organizations have stringent requirements for accuracy and content of battlefield information. Misunderstood, inaccurate, or incomplete information can have fatal consequences. As a result, military organizations spend a significant amount of time training their personnel in the use of standardized symbology for command, control, and tactical operations. A fully three-dimensional environment with terrain represented as an accurate height field and with 3D objects representing a multitude of protrusive features is a significant extension of the usual flat projected map environment. New 3D representations of the symbology and the underlying units are needed to make the most effective visualizations. However, it is also necessary to maintain contact with the training and knowledge that has gone into the 2D symbology. We have done this by taking a hybrid approach. We have implemented new 3D symbols but also labeled them with "signposts" bearing 2D symbols.

Battlefield information can be of many types from many different origins. For this study we concentrate on two types:

- Military Units
- Control Measures

Military units can be immediately divided into an organizational hierarchy such as in Fig. 1. The hierarchy is unit -> platoon -> company ->, etc.... The units can be foot soldiers, jeeps, tanks, and so on. In representing military units, there are two possibilities: (a) you have access to all information concerning the unit and know to which branch of the hierarchy it belongs, which is often the case for friendly units (at least for your units); (b) you have incomplete or totally missing information concerning the branch of the hierarchy to which the unit belongs (example: enemy units).

Control measures are different from the strongly organizational military units. They can be anything describing the battlefield setting or tactical information such as bridges, roads, mine fields, meeting points, air corridors, battlefield zone boundaries, etc. The "display" hierarchy here will be due entirely to spatial resolution. If the projected area of a control measure falls below a certain pixel threshold, the control measure will in most cases disappear rather than be subsumed into a group.

The units and control measure data are different from most GIS data[3] because the information is not permanently bound to a geographical location and can move around. This is especially so for the units and their hierarchy. In addition units and control measures may appear or disappear and should be movable by the user. Direct manipulation capability within the 3D environment is required for the latter.

2.1. Sources of Information

There are multiple sources of battlefield information. Each one has its own band-width and timing characteristics.

- Databases: databases contain information about both parameters of individual units and scenarios to animate those units (e.g., paths followed by motorized units). Adaptive paging techniques are needed to access at each moment the required information in very large databases.
- User Interface: At every moment the user can modify the parameters of the displayed units. or even add or remove units. Required bandwidth is small, but efficient responses to interface commands should be instantaneous. An effective

interface must have quick and easy features for interacting with units and all levels of the hierarchy (select units, move units, query and modify parameters, etc.).

- Real-time acquisition: Use of sensors or communication with computational simulations through the DIS protocol (see Sec. 5 below) provides real-time data. This requires the possibility to modify (move) large numbers of units (hundreds,...) each frame. Updates may not arrive systematically; they can appear at any time.

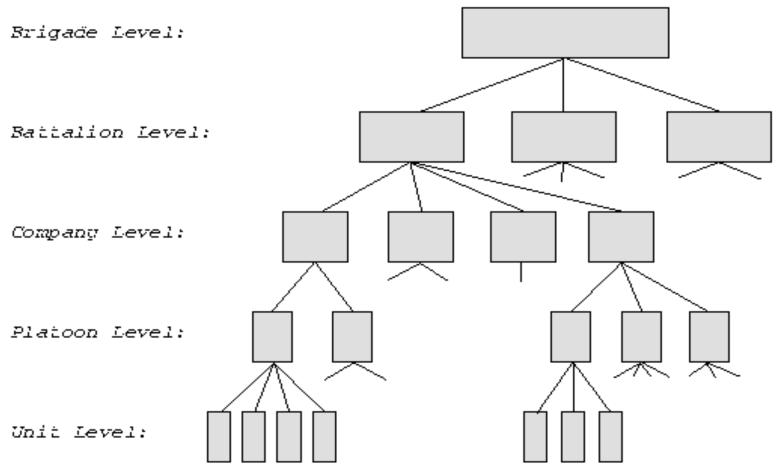

Figure 1: Partial view of a military (hierarchical) structure

2.2 Time Constraints

To maintain smooth navigation and immersion, a minimum rate of about 15 frames per second is the target. After deducting the time necessary for terrain retrieval, rendering, and other functions of the system, perhaps on the order of 10 milliseconds remain for symbology display. The point here is that, because of other demands on the time budget, only a small fraction of each frame time remains for the symbology. We attack this problem by using our organizational hierarchy. At the leaf node level, when we are dealing with individual units, we may also use a display hierarchy coupled with multiple levels of resolution. We will certainly use this display hierarchy when we don't have an organizational structure. One question, which we will attempt to answer below, is whether the organizational hierarchy is rich enough to handle hundreds or more units (at the leaf node level) while still meeting our time constraints. In other words, is there enough of a range of polygons--by displaying different combinations of levels in the hierarchy--to handle any likely time budget.

3. THE VGIS SYSTEM

To provide the context for the battlefield visualization and as a vehicle to work toward the "common picture of the battlefield", we have built VGIS (Virtual Geographic Information System), within which we display the 4D symbology. VGIS is a large, multifaceted project to allow navigation of and interaction with very large and high resolution, dynamically changing databases while retaining real-time display and interaction[4]. The system allows users to navigate accurate geographies (less than 1 meter resolution in some cases) with sustained frame rates of 15-20 frames per second. The user can not only see these terrains from any viewing angle but also buildings, roads, high resolution imagery draped on the terrain, and other features. As part of our 4D symbology capability, multiple vehicles, controlled by DIS transmissions from sensors or simulations, can move around the terrain. Underlying the system is a queryable GIS database that can be accessed through direct selection in the 3D visualization. The paging, caching, and advanced detail management algorithms allow flythroughs of datasets of any size and extent[5]. In fact the system has been demonstrated using terrain and image data of over 20 GB. There are both VR and workstation- based versions of VGIS and an OpenGL version that will run on a variety of platforms. Among several new capabilities planned for the system is the capability to automatically generate 3D representations of particular urban areas from 2D road and feature databases.

In order to present data at both high fidelity and high frame rates, we developed an algorithm for real-time level of detail reduction and display of the high resolution surface data[5]. The algorithm uses a compact and efficient regular grid representation and employs a variable screen-space threshold to bound the maximum error of the projected image. The appropriate level of detail is computed and generated dynamically in real time, allowing for smooth changes of resolution across areas of the surface. Typically the number of rendered polygons per frame is reduced by two orders of magnitude while maintaining image quality such that less than 5% of the resulting pixels differ from a full resolution image. One future project will be to add the very different organizational detail management to the surface data LOD method. We will then attempt to come up with a scheme that adaptively adjusts both levels of detail to get the best picture of the data.

VGIS can be used anywhere a traditional GIS can be used--and beyond. It can be used for urban planning, evaluations of vegetation, soil, waterway, or road patterns, flood planning, and many other tasks. In addition, the ability to have detailed 3D views and to jump to a different location to check the view opens new possibilities. Planners for new building or other facilities can see full 3D views from their prospective sites or can see the view from nearby existing buildings with their planned facility in plane. Urban planners can see the layout of streets, buildings, and parks on actual topography and can thus evaluate site lines, congestion, where sunlight strikes, etc. In addition, they can use the GIS database to display distributions of commercial activities, where schools or stores are located, where water mains run, and a myriad of other information.

The Army has shown great interest in immersive systems like VGIS that can navigate accurate terrains down to one meter resolution. The common picture of the battlefield will be built on highly accurate terrain visualizations with up-to-the-minute placements of military units and groups of personnel, display of current conditions for roads and bridges, visualization of weather effects or chemical clouds, display of military symbols and tactics, and much more. All must be presented and interacted with in real time, and the large amount of data must be organized into an efficient GIS for fast retrieval and full querying. The Navy is also interested in 3D tactical visualization systems, in this case for coastal and shallow water warfare. Finally, a system with immersive capabilities will have enhanced use for training or rehearsal. The military has much interest in training systems for rehearsing battle plans or for exploring and trying out tactical options at the command level. VGIS has also engendered interest for non-military application. Since the Georgia Tech team has high-resolution terrain and feature data for the Georgia Tech campus (site of the Olympic Village) and the downtown Atlanta area (where most of the Olympic venues are located), the security operation for the 1996 Olympics is interested in using VGIS for training their personnel and working out emergency scenarios.

4. OUR 4D SYMBOLOGY IMPLEMENTATION

4.1. Representation of Units

We have a rich set of representations at our disposal. The Army's 2D symbols[2] provide detailed symbolic representations for all units and all levels of the combat organization. These symbols are associated with the 4D symbols so they can impart their information to trained observers. The 2D symbols are retrieved via a "symbology server". Calls to the server retrieve 2D symbols with the appropriate marks showing the number of units in a given grouping or the level in the command structure. We have augmented this with a rich library of 3D graphical objects. To ensure maximum flexibility, libraries are loaded at run-time and storage of graphical objects is dissociated from the storage of the military symbols.

Although some previous work has been done on the 3D display of hierarchies[6] or of military units and control measures, little has been done on the application of hierarchical structures to these situations. Relevant research includes work on providing situation awareness in complex virtual environments[7]. This includes developing methods to take raw, unanalyzed data and rate its importance. These importance rankings are then used to rate activity around a series of "sentinels" placed by the user in a large scale battlefield scenario. The user then does not need to closely watch all the sentinel arrays simultaneously, but is rather alerted of important activity in any of them. In response the user can select the sentinel area and see the activity in detail. This approach, especially the methods for ranking activity, has relevance for our work.

The representation follows a few rules:

- The use of color is reserved to denote the affiliation of a unit (friendly, enemy, unknown). No other information can clearly be associated with colors. This is a rule established by the Army.

- Objects representing higher levels in the hierarchy are graphically simple (cube, tetrahedron, etc.). One type is associated with each level in the military hierarchy, and size increases as one moves higher in the hierarchy. This rule serves two purposes: faster to render, and easier/faster to recognize which level is displayed. Specifically pyramids represent platoons, cylinders with octahedral cross-sections represent companies, cubes depict battalions, and larger cubes depict brigades. The use of different shape objects is quite effective. We find these shapes can be discerned even for quite small (far away) objects on the terrain. Fig. 2 shows some shapes used in the levels of the hierarchy.

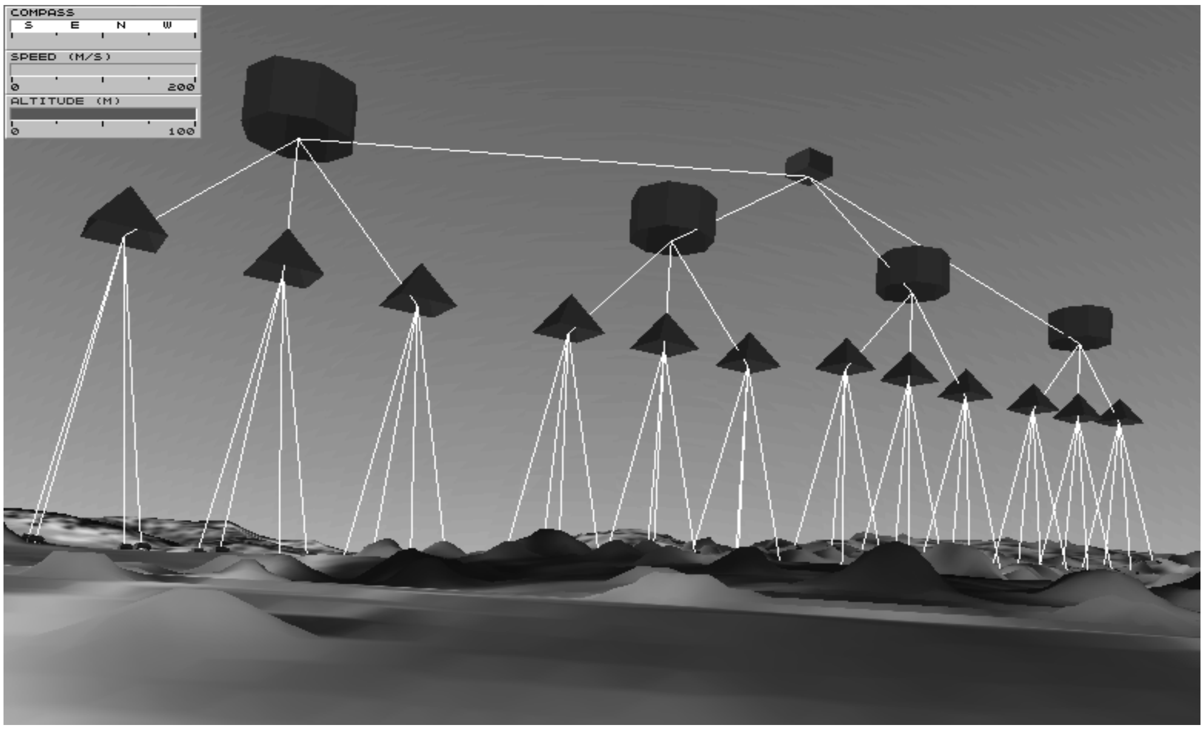

Figure 2: View of a hierarchy displayed in the geographical context given by VGIS

There is more information available on each unit than just its graphical representation and its location. This information can be obtained by actively querying any unit. Some data can also be passively displayed by each unit through a flag hanging above it and depicting symbolic information. (This is how the Army 2D symbols are displayed.) Since a flag is a 2D object in a 3D world, it is always rotated to face the user so that the information written on it is visible. The flags can be turned on and off by the user as a display option.

One can also display the spatial and temporal distribution of children for a given level of the hierarchy. Without the cost of representing each subunit, a simple "footprint" gives their spread. Since units can be spread widely (over several square miles for mobile units in a battalion), this knowledge can be critical in determining the layout of the battle. Temporal information can be used to update footprint patterns so that they show the changing formations as the battle progresses.

We studied a number of representations for the footprints. For example, we looked at the idea of painting the terrain over which units were spread with a distinctive color or pattern. We also considered embedding a thin, translucent polygonal solid in the terrain. The translucent colored part sticking up out of the terrain would form a "3D footprint". The painting or texturing requires an involved texture mapping procedure that can be quite time-consuming, especially for several footprints. Both the painting and 3D footprint option could cover wide areas because of the potential size of the footprints. This might at least partly obscure these portions of the terrain and the high resolution ground cover, road, and feature images that are also texture mapped on the terrain. We thus decided to use a simple set of 3D links or "pipes" to show the connections between a parent node and its children. We require the pipes to follow the terrain contours (so that they do not pass through hills, for example). Since it can be too time-consuming to query elevation for each node of high resolution terrains (which may be distributed a distances of 1M or less over hundreds of square miles), we use coarse resolution elevations from higher levels of the terrain quadnode structure. For this purpose we have modified VGIS with special fast calls to retrieve the coarse elevations. The pipes are placed far enough above the terrain that they do not embed themselves in higher resolution features. Fig. 3 shows a typical footprint structure (in this case between a motorized platoon, symbolized by a pyramid, and its vehicular units. The pipes are fast to draw, do not obscure the underlying terrain (or textures and features), yet provide the required information. An auxiliary question is where to place the parent node with respect to the rest of the footprint. If a command unit is identified, we place the parent over or near that unit. Otherwise, we use the centroid in the x-y plane to place the parent.

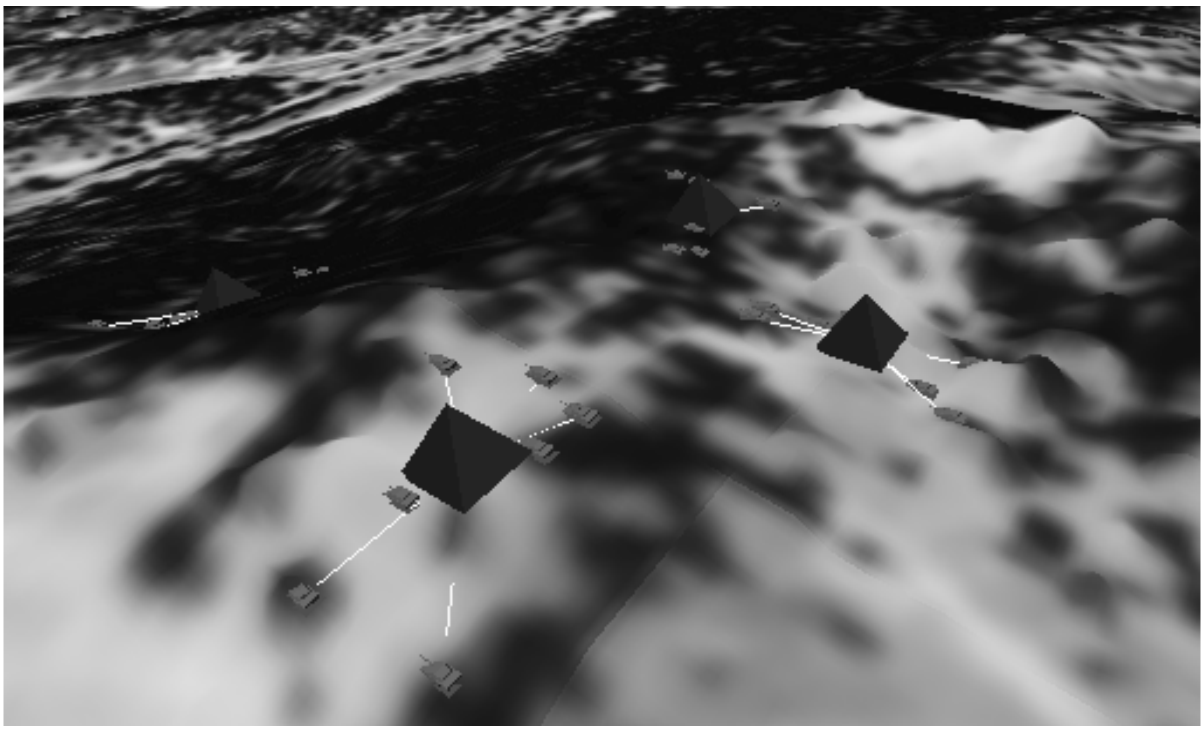

Figure 3: Representation of vehicular units and of their organization in platoons

4.2 Level of Detail Management

As we have said above, our detail management includes both display (objects at multiple levels of resolution) and hierarchical schemes[8]. We use both concurrently. Our choice of which scheme to employ is based on a rule, which is influenced by several factors including the user position and navigation speed (translation, rotation), the target frame rate, the object position on the screen, or a "benefit" weighting for the graphical object (representing its graphical complexity or importance). Since we integrate the symbology display into the VGIS system, we also use the viewing volume to determine what is visible and what is not for a given eyepoint. Only symbology within the viewing volume is drawn.

The level of the object detail or the organizational hierarchy that is displayed is constantly changing, based on the rule stated in the last paragraph. From frame to frame, children can condense into parent symbols or parents can explode into their children. Thus at every frame there could be objects that pop-up or disappear. Our tests show that this causes two perceptual problems:

(a) Since a set of children and their parent are located at different positions, the relationship between the appearing and disappearing units is not always clear.

(b) Unit pop-up creates an "event" on the screen, which often unnecessarily attracts the attention of the user.

There are some possible solutions:
(a) Several levels of the hierarchy can be displayed together, including some clearly visible linking.
(b) Children can appear before the parent disappears, at the location of the parent, and then smoothly move to their real locations before the parent object disappears.
(c) Children can appear in some smooth transition from fully transparent to solid (as the observer navigates closer) at the ends of their footprint links.

We have done some empirical studies to show that these methods can be effective. These studies have been especially for options (a) and (c). However, more tests need to be done. Also a detailed procedure for applying these options while maintaining real-time operation needs to be established.

4.3. Features and Interactions

The symbology code is integrated as additional libraries in the VGIS system. It uses the VGIS user interface: navigation (workstation window or immersive environment) and (noun-verb) interaction: first select one (or several) location(s) or object(s) using the "point-and-click" method, then select an action in the menu. The symbology libraries have a complete set of menu actions, which can be grouped in 3 sections.

- Information query. All represented units are interfaces giving access to entries in the data base. This information can be accessed by selecting the unit. Currently the database is not heavily populated, but the query method is available and will become more important once large databases are connected.
- Display options. Since user needs vary, there are options to adapt the choice of displayed objects--like the number of levels of the hierarchy displayed together, the highest/lowest level of the hierarchy that can be displayed, the possibility of freezing the display, switches to show the 2D flags described above, the subunits footprints, and so on. One option allows display of the whole hierarchy at once, using the vertical dimension to show the hierarchy levels (only basic units are then positioned on the ground). It creates a very effective hierarchical tree, combining geographical information (horizontal position) and hierarchical information (vertical position). (See Fig. 2). Of course, this display method slows rendering since everything is visible, and is not suited for fast navigation.
- Interaction with units. All basic operation (add, move, remove, change affiliation, etc.) on units are possible.

5. INCLUDING DIS - GAINING THE 4TH DIMENSION

Increased computing power has made possible the real-time simulation of thousands of entities by a single computer. Complex, realistic, and highly interactive virtual worlds can be created by linking multiple simulations over computer networks, thus making large scale training exercises feasible. However, in order to maintain interactivity, object positions and orientations must be updated at least 10 times per second. Unfortunately, for large scale distributed simulations (> 100,000 entities), current networking technology cannot adequately handle the vast amounts of data that must be communicated between the simulations and the display device (or between the simulations themselves) to maintain real-time updates.

The Distributed Interactive Simulations (DIS) standard has been established to provide a protocol that enables distributed simulations to communicate with each other[9,10]. DIS reduces the amount of data transmitted through the use of local databases, best effort broadcasting, and the implementation of dead-reckoning for simulated entities. Using local databases eliminates the need to transmit detailed descriptions of entity models and terrain data. Best effort broadcasting does not provide transmission verification, and therefore reduces the amount of network traffic by eliminating re-transmissions. Dead-reckoning further reduces network traffic by allowing a simulation to lower the frequency of object position updates. The simulation specifies which dead-reckoning algorithm should be used to estimate an object's position and only transmits position updates when the dead-reckoning model differs from the object's actual position by a threshold value. The use of the DIS protocol is not restricted to computer simulations. DIS is also intended to communicate information from real vehicles moving on instrumented ranges (e.g. the Army's National Training Center). Thus a variety of sensor information can be transmitted using the DIS protocol.

By accepting data from simulations or sensors that adhere to the DIS standard, we are able to add a 4th dimension--time dependence-- to our symbology visualization. The data provided by DIS can be hierarchically organized and displayed within real-time constraints by using the level of detail methods described above. At the moment DIS does not provide organizational information. However, this is likely to change in future versions of the DIS protocol. At the moment, we provide a separate organizational structure for the DIS entities. In the future this will be augmented by information from the new DIS protocol. It is probable, however, that we will use organizational information from more than one source, since it is likely to be incomplete and come from multiple sources. Our task will then be to order the priority of sources so that one can override the others in case of conflicts.

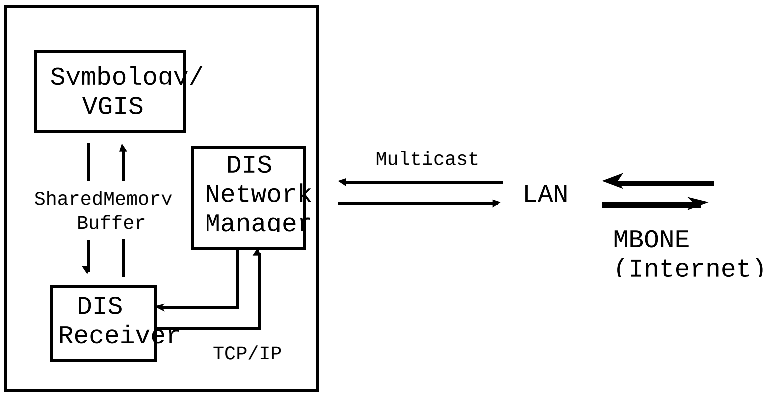

Figure 4: Connection to the network using the DIS capability

As shown in Fig. 4, DIS capability has been provided to the symbology libraries through the addition of two independent processes. The first process is the Loral DIS Network Manager. The Network Manager is responsible for receiving and buffering the multicast DIS packets from the local network. The second process is the DIS Receiver, which establishes a TCP/IP connection with the Network Manager and registers the type of DIS data that it is interested in. Since the Network Manager buffers the DIS packets, the Receiver is able to receive the data from the Network Manager asynchronously. The Receiver maintains information on all the entities in the simulation, and is responsible for performing the dead-reckoning calculations. The Receiver also performs the translation from the coordinate system used by DIS to the coordinate system used by VGIS. The Receiver process communicates to VGIS through a shared memory buffer. The most recently calculated position and orientation information for each entity is kept in the buffer, allowing the symbology routines to access it whenever they can.

6. SOME SCENARIOS

The scenarios described here use multiple resolution terrain elevation and imagery data from Fort Hunter Liggett in California. The full dataset is several kilometers on a side and has a maximum terrain resolution of 2 meters.

We have set up a scenario using our DIS capability and LOD management schemes. This replicates a battlefield management scenario with many units moving in a realistic fashion. The position of each unit is updated between every frame. These updates include horizontal translation and vertical positioning. For grounded units, vertical positioning is needed for both hierarchical position (based on level of detail) and terrain-elevation positioning. In this scenario two groups of units are depicted; friendly tanks and helicopters and enemy tanks. The friendly tanks are in a V-shaped formation, as are the enemy tanks. The helicopters are in a line formation. The opposing forces move towards one another and eventually interpenetrate spatial areas. (See Fig. 5.) Our detail management and navigation tools allow the user to fly around and observe this unfolding scene in real-time.

We have also developed a larger scale hierarchical scenario to further test our detail management schemes. This is a brigade-level depiction. It has 5 hierarchical levels showing brigade, battalion, company, platoon, and basic unit formations. All these are deployed on the Hunter-Liggett terrain. The total number of basic units is approximately 250. (See Fig. 6 for an overall depiction of the hierarchy.) The time to display each frame of the total symbology (with no organizational detail management) is about 0.1 second. This is in addition to the time needed to render the terrain and slows interaction with and navigation of the visualization significantly. With organizational detail management (using a default set of parameters to determine at what distance each level of the hierarchy should be displayed), the time to render the symbology drops to 0.015 seconds. There are no longer delays in navigation and interaction. Thus our detail management scheme is successful for a moderately sized array of units. We believe that our organizational hierarchy (with 4-5 nodes on each level) is sufficiently flexible to retain real-time frame rates even for larger collections of objects. We plan to construct even larger scenarios to test this thesis.

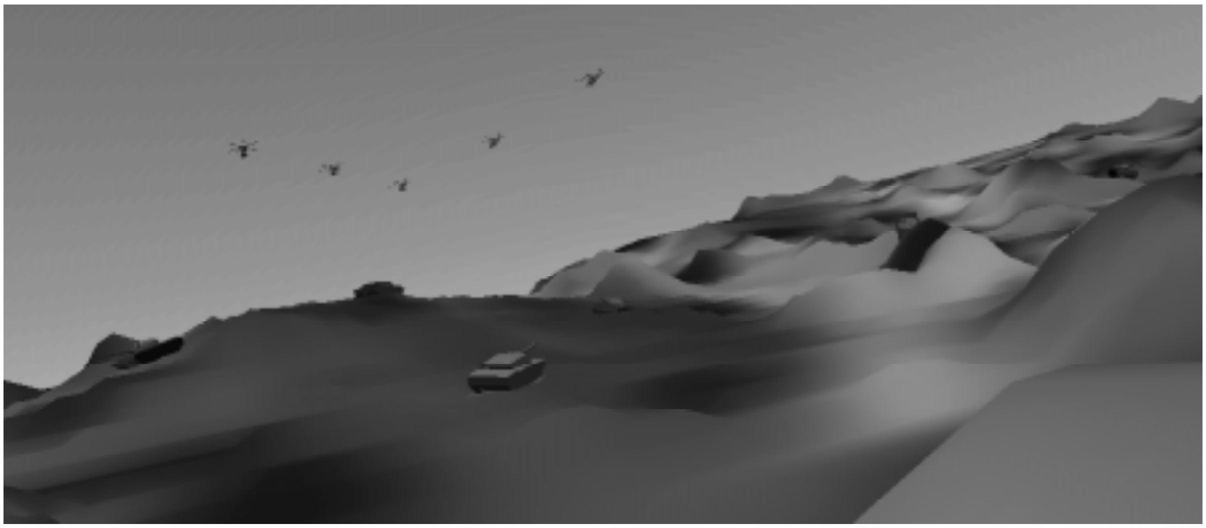

Figure 5: View extracted from a scenario displaying a simulation (obtained using DIS capability)

7. CONCLUSIONS AND FUTURE WORK

We have developed a 4D symbology and shown how it can be managed using both a display and an organizational hierarchy. These hierarchies can significantly reduce image clutter caused by many moving objects, can provide grouping structures to aid understanding, and offer significant control over detail so that real-time frame rates and interactions can be retained. DIS capability greatly strengthens the time dependent aspects of the symbology. It also allows the distribution, sharing, and joint visualization of symbology data. With DIS our symbology/VGIS system immediately becomes a distributed system where multiple instances of the visualization can be run sharing common data and all having access to immediate updates.

We have worked out some military scenarios for our symbology system. These show time-dependent symbology in a realistic setting and also show the use of an organizational hierarchy involving hundreds of units. For the latter, we demonstrate that our detail management scheme greatly reduces the rendering time for the symbology and that an organization involving hundreds of units placed on a realistic, high resolution terrain can be navigated in real-time. The 4D symbology structure is also flexible and general. It can be applied to many other types of data including those without a strong spatial dependence.

We will continue working on several open questions. Our investigations will be extended to symbologies involving hundreds to thousands of moving units. The hierarchical symbology organizations will move in time and will change their structures. These studies will allow us to give our detail management approach a full workout and decide conclusively about its flexibility for handling large scenarios. We also expect to study a variety of nonmilitary applications. These will include applications that are not geographically based and may not have any inherent 3D spatial composition. However they will have a strong organizational hierarchy. For these applications we will use the 3D space to detail and elucidate the organization structure. We will also look further at the question of building hierarchies from unstructured data. This will include data that comes from DIS, which in its present form does not provide organizational structure. We will expand on our capability to obtain and integrate organizational and structural data from different sources. Often hierarchies will be incomplete or subject to change. For example, knowledge of enemy military groupings is likely to be incomplete. It will also be modified based on intelligence from a variety of sources. We will develop mechanisms to integrate knowledge such as this into updated hierarchical structures.

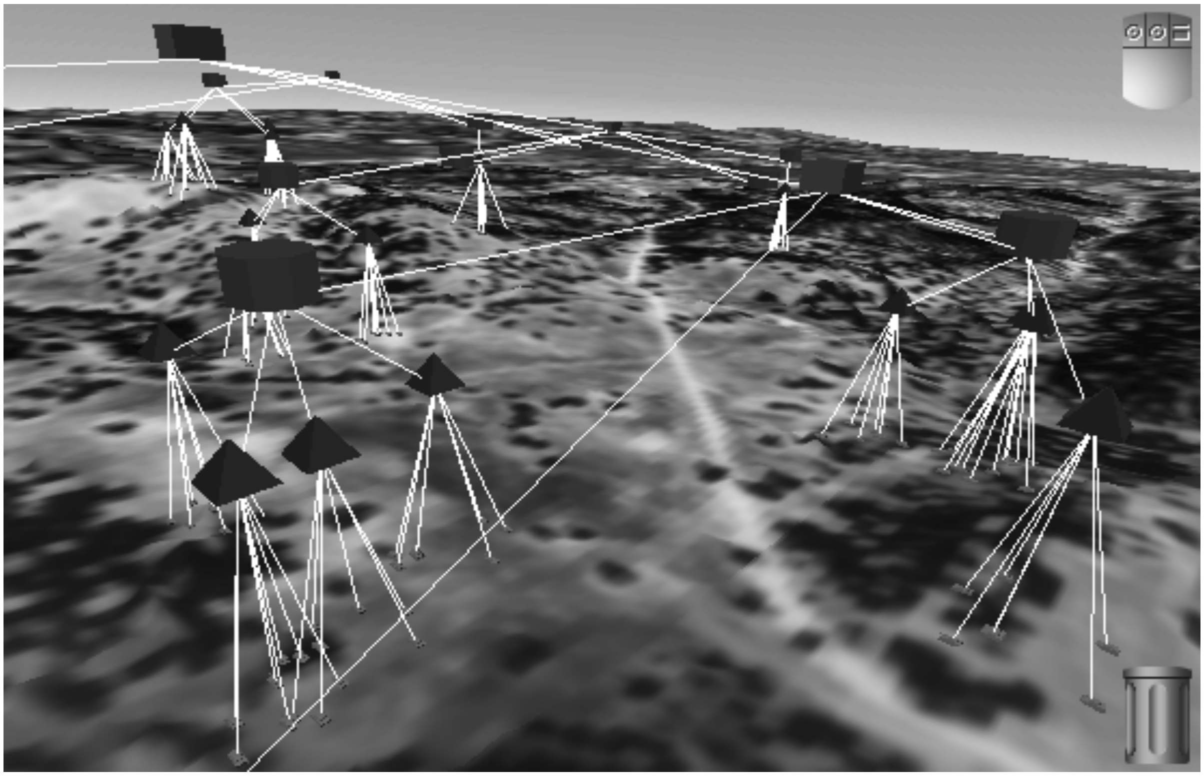

Figure 6: View extracted from a scenario displaying a large hierarchy

8. ACKNOWLEDGEMENTS

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