Visualization for Tracking Battlefield Events in Time and Space for C^2

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GeoTime For C^2

Abstract

Analyzing people, equipment, organizations and their activities over time is increasingly a key concern for command and control. The objective of our research has been to develop a method to capture and visualize the spatial and inter-connectedness of this information over time within a single, highly interactive picture. A novel visualization technique for displaying and tracking events, people, and equipment within a *combined temporal and geospatial* display has been developed into a demonstratable prototype called GeoTime in order to determine potential utility. The focus of this paper is on land force commanders and staff. However, we believe the concept is applicable to a wide variety of government and business analysis tasks.

Introduction

Understanding people, equipment, organizations and their activities over time is increasingly a key concern for command and control in any deployment. In situations of asymmetric warfare, stability and support operations and peace support operations, tracking relatively small and seemingly unconnected events over time becomes a means for gaining insight into enemy or insurgent behavior. Local cultures, characters, organizations and their behaviors play an important part in planning and mission execution. Small attacks come from unknown assailants over long periods of time, making it difficult to see patterns. Relationships between events, suspects, known personalities and organizations are hard to make. Information obtained is piecemeal – a puzzle. The key dimensions of this information are who, what, where, when, how, why and with-whom.

Visualization and interaction techniques have significant potential to improve the productivity of complex human cognitive tasks. They serve as external mental aids [Tufte, 1990]. When information is presented visually, efficient innate human capabilities can be used to perceive and process data. 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 benefits translate into significant system and task related performance objectives [Wright, Kapler, 2002].

Background

Many visualization techniques and products for analyzing complex event interactions only display information along a single dimension, typically one of time, geography or a network connectivity diagram.. Each of these types of visualizations is common and well understood. For example a time-focused scheduling chart such as Microsoft (MS) Project displays various project events over the single dimension of time, and a Geographic Information System (GIS) product, such as MS MapPoint, or ESRI ArcView, is good for showing events in the single dimension of locations on a map. There are also link analysis tools, such as Netmap (www.netmapanalytics.com) or Visual Analytics (www.visualanalytics.com) that display events as a network diagram, or graph, of objects and connections between objects. Several systems exist for tracking highly connected information, most developed for intelligence and police purposes [Harries, 1999]. Analyst Notebook and CrimeLink provide tools for organizing and arranging fragments of information into visualizations intended to help the analyst make sense of the complex relationships. These tend to be one dimensional representations that show either organizational structures, timelines, communication networks or locations. In each case only a thin slice of a multidimensional picture is portrayed. Some of these systems are capable of using animation to display time. Time is played back, or scrolled, and the related spatial or other display changes to reflect the state of information at a moment in time. However this technique relies on limited human short term memory to track and then retain temporal changes and patterns. Another visualization technique called "small multiples" uses repeated frames of a condition or chart, each capturing an increment moment in time, much like looking at sequence of frames from a film laid side by side. Each image must be interpreted separately, and side-by-side comparisons made, to detect differences. This technique is expensive in terms of visual space since an image must be generated for each moment of interest, which can be problematic when trying to simultaneously display multiple images of adequate size that contain complex data content.

The objective of our research has been to develop a way to visualize the spatial and temporal dimensions and connectedness of the problem within a single picture, and to make it feasible for use by the commander and staff within the battlefield.

In the course of researching concepts and developing systems for ARDA's Geo-Spatial Intelligence Information Visualization Program (GI^2Vis) and C^2 users, we have developed a novel visualization technique for displaying and tracking events, people, and equipment within a *combined temporal and geospatial* display. This concept has been developed into a demonstrable prototype called GeoTime in order to determine the potential utility by both intelligence analysts and commanders.

The GeoTime Visualization Concept

A visualization technique was needed to improve perception of movements, events and relationships as they change over time within a spatial context. A combined temporal-spatial space was constructed in which to show interconnecting streams of events over a range of time in a single picture. Put simply, events are represented within an X,Y,T coordinate space, in which the X,Y plane shows geographic space and the Z-axis represents time into the future and past (see Figure 1). In addition to providing the spatial context, the ground plane marks the *instant of focus* between before and after; Events along the timeline "occur" when they meet the surface. Events are arrayed in time along *time tracks,* which are located wherever events occur within the spatial plane.

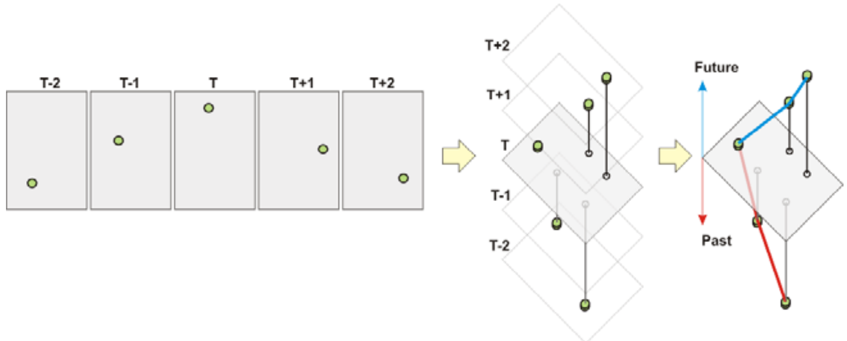


Figure 1:
Diagram showing how individual frames of movement are translated into a continuous spatiotemporal representation

Spatial Time-Tracks

Spatial Time tracks make possible the perception of *where* and *when*. They are the primary organizing elements that support the display of events in time and space within a single view. Time-tracks represent a stream of time through a particular Location and are represented as a literal line in space. Each unique location of interest will have one spatial timeline that passes through it. Events that occur at that location are arranged along this timeline according to the exact time or range of time at which the event occurred.

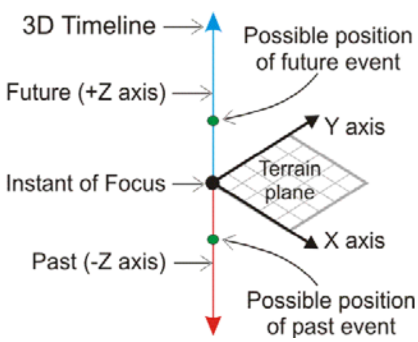


Figure 2
Diagram of 3D Timeline configured to display past as down and future as up

A single spatial view will have as many timelines as necessary to show every Event at every location within the current spatial and temporal scope. In order to make comparisons between events and sequences of events between locations, the time range represented by the timelines is synchronized. In other words the time scale is the same for every timeline.

There are three variations of Spatial Timelines that emphasize spatial and temporal qualities to varying extents. Each variation has a specific orientation and implementation in terms of its visual construction and behavior. The user may choose to enable any of the variations at any time during runtime.

3D Z-axis Timelines

3D Timelines are oriented normal to the terrain view plane and exist within its coordinate space as shown in Figure 3.

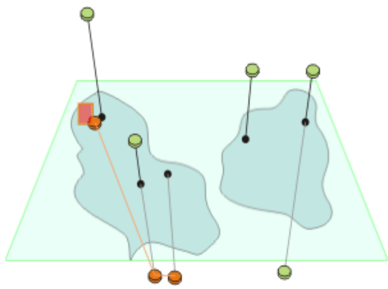


Figure 3
Diagram showing how 3D Timelines pass through terrain locations. 3D timelines are locked in terrain space and are affected by changes in perspective.

3D Viewer Facing Timelines

3d Viewer-facing Timeline are similar to 3D Timelines except that they rotate about the instant of focus point so that they always remain perpendicular to viewpoint from which the scene is rendered. This is shown in Figure 4.

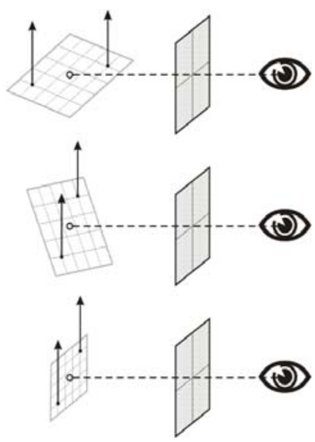
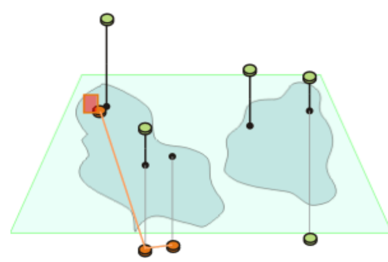
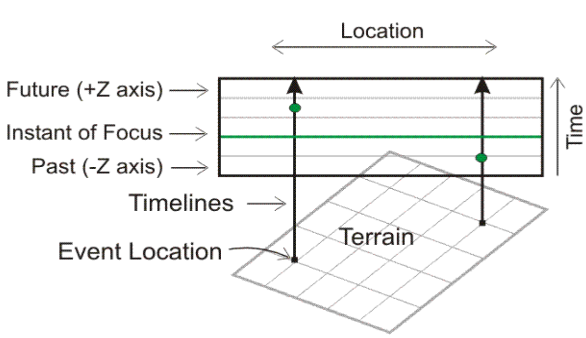


Figure 4
Diagram showing how viewer facing timelines rotate to face the viewpoint no matter how the terrain is rotated in 3 dimensions.



Linked TimeChart Timelines

Linked TimeChart Timelines are timelines that connect a 2D grid in screen space to locations marked in the 3D terrain representation. As shown in Figure 5, the timeline grid is rendered in screen space as an overlay in front of the 2D or 3D terrain.



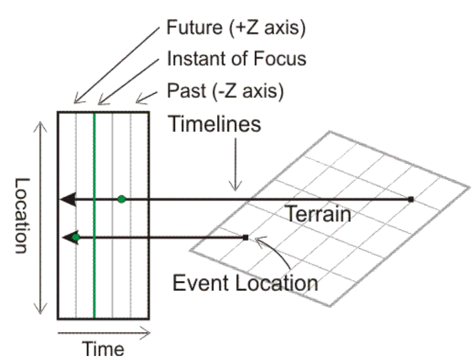


Figure 5
Diagram showing how TimeChart timelines are connected to terrain locations.

The GeoTime Information Model

An information model based loosely on Davidsonian semantics [Davidson, 1980] is used to support the representation of information in GeoTime. The following objects types are employed in GeoTime.

Entities *(people or things)*
represent any thing related to or involved in an event including people, objects, organizations, equipment, businesses, observers, affiliations etc.

Locations *(geospatial or conceptual)*
represent a place within a spatial context, such as a geospatial map, a node in a diagram such as a flowchart, or even a conceptual place such as "OZ".

Events *(occurrences or discovered facts)*
represent any action that can be described. The following are examples of events

- Bill was at Toms house at 3 pm
- Tom phoned Bill on Thursday
- A tree fell in the forest at 4:13 am, June 3, 1993
- Tom will move to Spain in the summer of 2004

Events store the times at which the action took place.

These basic information types are combined into groups using Associations. An association is an information object that describes a pairing between two objects. For example, in order to show that a particular entity was present when event occurred, an Association is created to represent that Entity X "was present at" Event A. An association also exists to link Event A to a particular Location. In GeoTime, groups of associated elements have been defined to represent certain classes of occurrences and relationships. These groups have specific visual expressions and interactive behaviors in the display. The defined groups are described in Figure 6. A variation of the association type is used to define a subclass of these groups to represent user hypotheses. In other words, groups can be created to represent a guess or hypothesis that an event occurred, that it occurred at a certain location or involved certain entities.

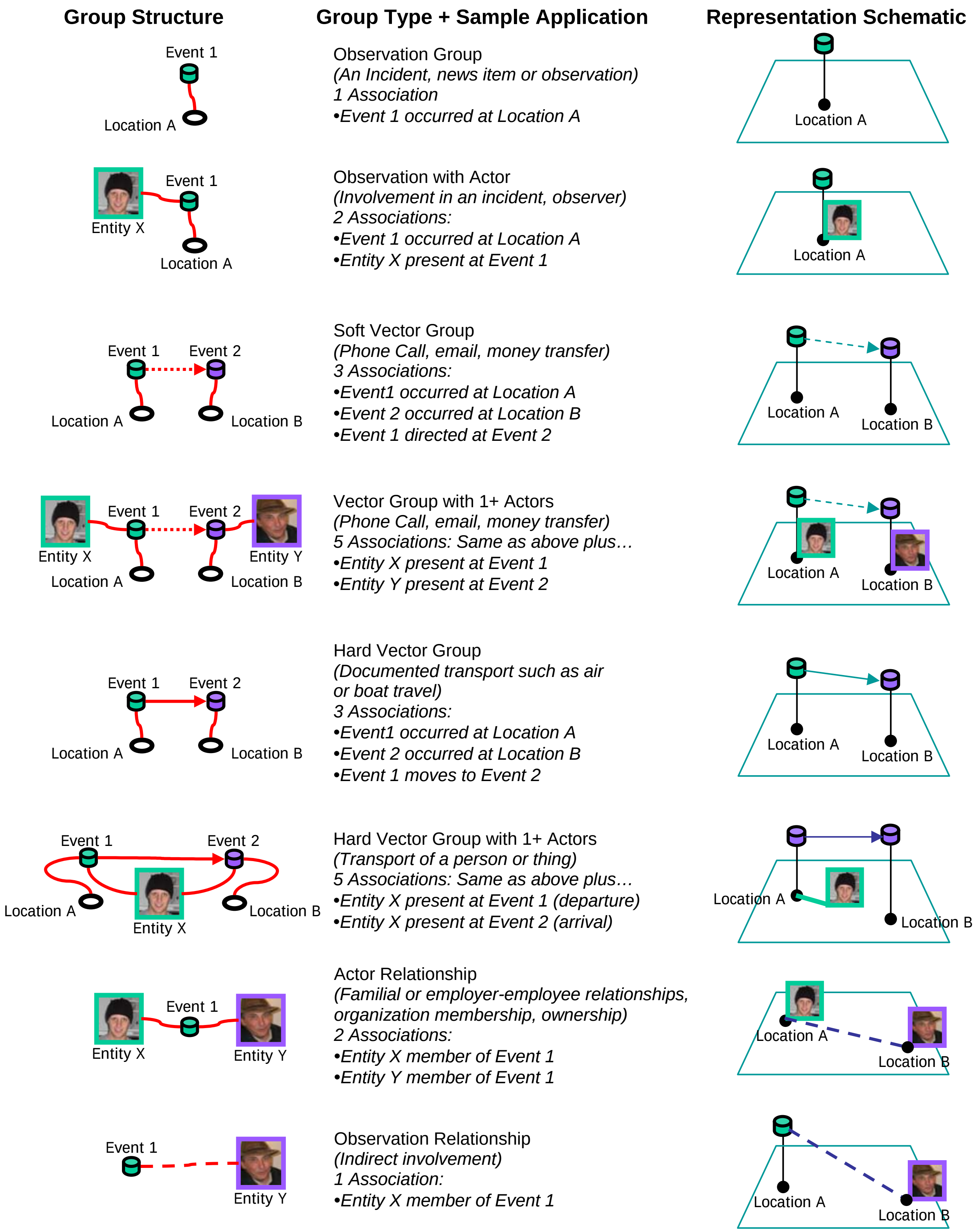


Figure 6 –Example Entity Activity Groups

Information Interaction within the Spatio-Temporal Workspace

In order for GeoTime to move beyond a visualization concept to a usable prototype, several user interactions within the combined spatio-temporal viewer were necessary. In addition to familiar data interactions such as selection, filtering, hide/show and grouping that operate as commonly expected, the following interactions were specifically developed or customized to work within the GeoTime environment.

Temporal Navigation

The Time and Range Slider is a linear time scale that is visible underneath the visualization representation. This control contains sub controls/selectors that allow control of three independent temporal parameters: the Instant of Focus, the Past Range of Time and the Future Range of Time. The time range visible in the time scale of the time slider can be expanded or contracted to show a time span from centuries to seconds. Clicking and dragging on the time slider anywhere except the 3 three selectors will allow the entire time scale to slide to translate in time to a point further in the future or past.

Simultaneous Spatial and Temporal Navigation

Common interactions such as zoom-box selection and saved views are provided. In addition, simultaneous spatial and temporal zooming has been made possible to allow the user to quickly move to a context of interest. In any view, the user may select a subset of events and zoom to them in both time and space using the Fit Time and Fit Space functions. Within the Overlay Calendar views, these actions happen simultaneously by dragging a zoom-box on the time grid itself. The time range and the geographic extents of the selected events are used to set the bounds of the new view.

Association Analysis

Functions have been developed that take advantage of the association-based connections between Events, Entities and Locations. These functions are used to find groups of connected objects during analysis. Associations connect these basic objects into complex groups (see Figures 6) representing actual occurrences. These associations can be followed from object to object to reveal connections that are not immediately apparent. Association analysis functions are especially useful in analysis of large data sets where a quick and efficient method to find and/or filter connected groups is desirable. For example, an Entity maybe be involved in events in a dozen locations, and each of those events may involve other Entities. The association analysis function can be used to display only those locations on the visualization representation that the entity has visited or entities that have been contacted. Two simple association analysis functions have been implemented: Expanding Search and Connection Search.

1. *Expanding Search*

The expanding search function allows the user to start with a selected object(s) and then incrementally show objects that are associated with it by increasing degrees of separation. The user selects an object or group of objects of focus and clicks on the Expanding

Search button - this causes everything in the visualization representation to disappear except the selected items. The user then increments the search depth - objects connected by the specified depth are made visible in the display. In this way, sets of connected objects are revealed.

2. *Connection Search*

The Connection Search function allows the user to connect any two objects by their web of associations. The user selects any two objects and clicks on the Connection Search tool. The connection search algorithm automatically scans the extents of the network of associations starting from one of the objects. The search will continue until the second object is found as one of the connected objects or until there are no more connected objects. If a path of associated objects between the target objects exists, all of the objects along that path are displayed and the depth is automatically displayed showing the minimum number of links between the objects.

Application of GeoTime to Command and Control

The authors envision a spectrum of applications for the GeoTime concept in Command and Control and Intelligence. These applications may be roughly defined by a space bounded in two dimensions – data character and operator mode.

Data character is a factor of the source, volume and connectedness of the data. At one pole, the data may be discrete and voluminous, and the other, focused and tightly interconnected. Many operator modes are also possible. The extremes might be described as information consumer vs. information creator. Figure 7 shows how these sets of poles can define a range of C^2 use-types. Several specific use cases have been developed in cognitive task analyses and reviews with analysts and commanders.

Visual History of Reports: "Information Consumer"

The GeoTime display can be used to get an instant view of activity at any time/space coordinate. Within a C^2 environment, standard activity reports, such as those used and produced by systems like ASAS Lite, CRIMELINK, FBCB2, MCS and others can be imported and translated into GeoTime elements. Over the course of weeks or months, hundreds to thousands of events could be stored and reviewed with a system such as GeoTime.

GeoTime For C^2

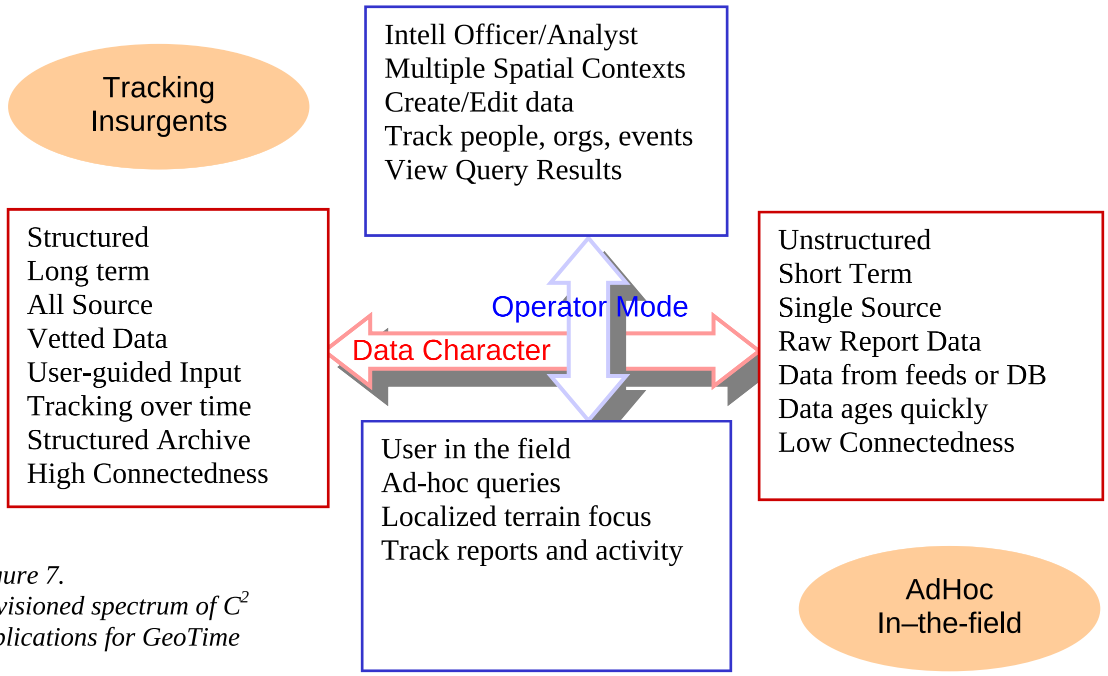


Figure 7.
Envisioned spectrum of C^2 applications for GeoTime

Insurgent Tracking Analysis: "Information Creator"

An investigator, such as an intelligence officer, could use GeoTime to generate an interactive log of events gathered during the course of long-term investigations or tracking task. Existing reports and query results are combined with user input data, assertions and hypotheses. The investigator can replay events and understand relationships between multiple targets, movements and the events. Patterns of travel, communications and other types of events can be understood. Repetition, regularity, bursts or pauses in activity are easily apparent.

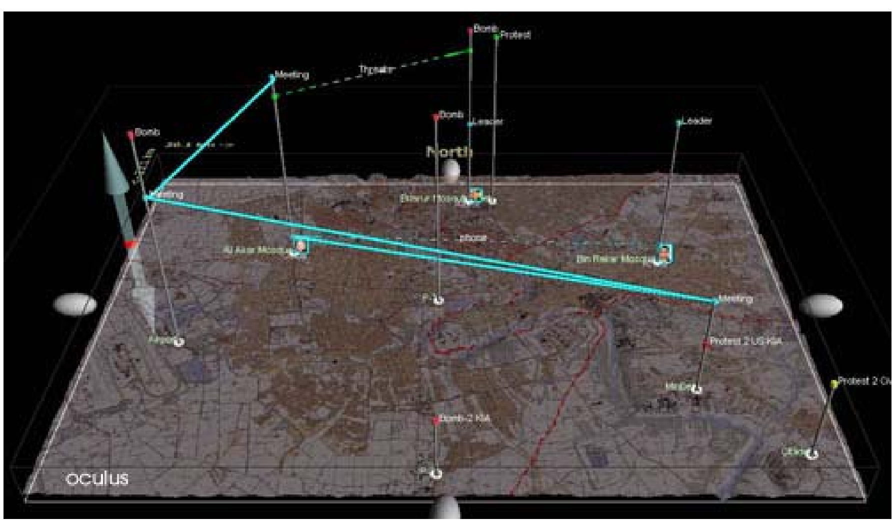


Figure 8.
Screenshot of the GeoTime prototype showing asymmetric events and entity tracking over time in a fabricated scenario.

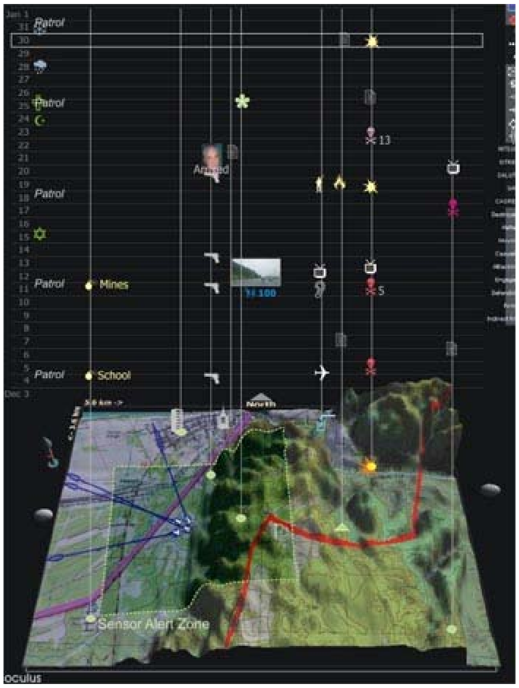


Figure 9. Screenshot of the GeoTime prototype in calendar mode showing recent events within a localized area.

Evaluation and Conclusions

Limited demonstrations of GeoTime running against unclassified databases of simulated battlefield events and analysts training scenarios show that the following types of information are quickly revealed.

- What significant events happened in this area in the last X days?
- Who was involved?
- What is the history of this person?
- Who have they communicated with?
- Where might they have met with other people?
- Where are the hot spots?
- Has this type of event occurred here or elsewhere in the last Y years

Additional GeoTime evaluations are planned in the near future, including several technology exploration exercises with subject matter experts, as well as more formal task impact and evaluation experiments.

The GeoTime prototype demonstrates that a combined spatial and temporal display is possible, and may be highly effective when applied to analysis of past and future events within a geographic context, such as an area of operation. Ongoing research will include further experimentation to explore and develop the full potential of the GeoTime visualization tool for command and control.

Acknowledgement

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