Visualization of Events in a Spatially and Multimedia Enriched Virtual Environment

Leonidas Deligiannidis
The University of Georgia
Department of Computer Science
Athens, USA
ldeligia@cs.uga.edu

Farshad Hakimpour
The University of Georgia
Department of Computer Science
Athens, USA
farshad@hakimpour.com

Amit P. Sheth
The University of Georgia
Department of Computer Science
Athens, USA
amit@cs.uga.edu

***Abstract*—Semantic Event Tracker (SET) is a highly interactive visualization tool for tracking and associating activities (events) in a spatially and Multimedia Enriched Virtual Environment. SET provides integrated views of information spaces while providing overview and detail to improve perception and evaluation of complex scenarios. We model an event as an object that describes an action and its location, time, and relations to other objects. Real world event information is extracted from Internet sources, then stored and processed using Semantic Web technologies that enable us to discover semantic associations between events. We use RDF graphs to represent semantic metadata and ontologies. SET is capable of visualizing as well as navigating through the event data in all three aspects of space, time and theme.**

Keywords-component; Multimedia Information Systems, User Interfaces

I. Introduction

SET is a tool that combines several technologies to provide a framework that enhances the user's ability to interact with its visualization component and interpret the spatiotemporal relations between events in a far more effective way than in traditional information visualization tools. Specifically, in conjunction with our back-end semantic discovering tools and algorithms [2][3][4], SET provides the ability to visualize complex relationships, identify new patterns of significance, and provides interactive probing along intelligent guidance, all within a 3D visualization media and spatial enhanced environment.

The ability to use ontology driven metadata extraction from diverse multimodal sources such as unstructured, semi-structured and structured data, forms the basis for new approaches to semantic analytics. Scenarios that employ the "exploratory" use of SET involve recognizing associations of heterogeneous data sources such as associating audio data (phone logs and conversations, frequencies of calls, call signs, etc), with geospatially-related information (e.g. weapons storage facilities, known locations of terrorist cells), with information from "trusted" structured and semi-structured sources (e.g. source pedigree, personal associations with reported events or individuals), information from unstructured sources (emails, and handwritten notes), in a way that an analyst can "recognize" and visually explore the importance of particular evidentiary "cues" among many others.

Our main focus is to visualize "events" in a Virtual Environment by providing visual information about position and temporal relationships between a set of semantically related events. We enhance the environments with drilling capabilities that allow easy access to digital media such as text documents, pictures, audio and video clips. Using SET, an analyst is able to calibrate and interactively guide the analysis of underlying heterogeneous multimedia data with the help of ontologies and multimodal interactivity where the result is rendered in 3D, with the ability to drill down and see the "connected dots" from different perspectives (spatiotemporal and thematic dimensions).

II. Background

Data exploration and analytics through visualizations require extensive functionality in both the system and the interactive interface [13]. The data presentation (i.e. rendering component) should provide the user with the capabilities to explore her dataset, highlight important data features such as relationships, similarities and anomalies, query the dataset to narrow down the result, organize the result in her logical groupings so that she can comprehend the data. Static images have limited capacity to supply enough information for the user to conceive appropriate reasoning. Therefore, a visualization analytics environment should provide an interface where the user can interact dynamically and in real time with the system. Furthermore, we believe that the interface should be easy to master because powerful tools that are difficult to master are normally abandoned by the user community.

An event object represents a change in the state of the world that affects the state of one or many entities. To visualize and analyze event information we deal with three aspects of events, namely space, time and theme.

- Where it took place: its location coordinates, such as a named place or as attributes such as latitude, longitude, and elevation.
- When it took place: its timestamp, time interval of the event, or it can be described with relevance to a previous

event such as event “A” happened two hours before event “B”.

- What it is: its name, type, class, entities involved, etc.

By using maps we can visualize the position of events. Maps have been used for years to illustrate the space around us and provide a geographic understanding. With today’s growth of geospatial information, detailed maps can be constructed on demand that can be enhanced with digital terrains and satellite imagery such as Google Maps (www.google.com/maphp) and Google Earth (http://earth.google.com/). The ability to link other forms of display such as tables with maps and images provides analysts with summary information in the context of space and time. As an example, elegant interaction techniques and devices (the TouchTable) for manipulating, visualizing, and studying maps have been implemented by Applied Minds Inc (http://www.touchtable.com/). Their latest tools can also build physically 3D terrains of maps.

MapPoint and ESRI ArcView can display position of the events on a 2D map. However, time is an essential aspect of an event. Lifelines [5] and Microsoft (MS) Project display attributes of events over the single time dimension. Netmap (www.netmapanalytics.com), Visual Analytics (www.visualanalytics.com), and Analyst Notebook (www.i2inc.com) display events as a graph of objects with connections between them. We believe that to help the user perceive different aspects of an event we need to visualize events both in time and space.

While research in GIS for event visualization is in the early stages, results seem promising for the 3D environments. First results show how it is possible to visualize paths or track activities but there is no animation or support for visual analytics and most of the early work is concentrated in the “overview” aspect of visualization rather than the “detail” needed in many cases for visual analytics [8][9].

A pioneering visualization system that displays information on a highly interactive 3D environment that consists of a 3D terrain is GeoTime [10][11][12]. In GeoTime, events are displayed onto a 3D terrain to assist an analyst in correlating events and geographical locations of activities. GeoTime demonstrates that a combined spatial and temporal display is possible, and can be an effective technique when applied to analysis of complex event sequences within a geographic context.

The semantic aspect of the events plays an important role to our understanding. Type of an event, entities effected or associated with the event are examples of knowledge important in our understanding of an event. Semantic Web technologies already play a crucial role in the integration of spatiotemporal information sources [1] as well as associating events with thematic objects and spatiotemporal information [7]. Using semantic associations can further enhance the illustration of a service. For example, using SET it is possible to discover an entity such as a person that is related to an organization which in turn is involved in an event. Then the associated person and its related information (such as his photo) can be visualized by our system.

III. THE SET PLATFORM

SET is a highly interactive visualization environment used for tracking and associating events (activities) using Virtual Reality technology in an environment enriched by spatiotemporal and multimedia information.

SET consists of four major components: (1) the “Event Data Store” (EDS), which is accessible via a Web service and provides querying and extraction of event information, (2) the “Map Renderer” (MR), which is either a Web service or an application server that provides geo-referenced maps, (3) the “Semantic Event Tracker Visualizer” (SETV), which is the visualization component of SET that utilizes Virtual Reality and GIS services to render and manipulate the events, and (4) the “Speech Communicator” (SC) that consists of a speech recognizer and a speech synthesizer used for SET-user interaction.

SET interacts with the EDS via a browser and a set of Web Services. EDS provides specialized query processing for event data. These query services allow us to search for events: (1) in spatial proximity of a target point, (2) in temporal proximity of a target point in time and (3) in semantic proximity of a target object. Semantic proximity of an object is measured by the associations found between an object of interest and events.

The query services also accept any combination of the three proximity constraints. Such queries can be performed through a user interface prepared for Web browsers. The interface allows the user define the following constraints:

1. Time: Entering date and time of day of the event.

2. Space: Specifying a target location by address or by clicking on the map. In the case of entering an address, the client geo-codes the address using Google’s geo-coding service on the client-side and then provides the coordinates as a parameter in the query.

3. Semantics: semantics of events may be constrained by the user in two ways: first, by specifying an event type, the user can narrow down the type of events; second, by providing keywords that we associate with the events in our data set.

4. Spatiotemporal proximity: users define a spatial and a temporal proximity of the target point for events retrieval.

The result query is passed to the SETV component of SET which visualizes the events in space and time. SETV uses the MR component to render the 2D map which is based on the Latitude and Longitude of each event.

IV. TRACKING EVENTS IN SET

Once the “result events” are identified by EDS, they are sent to the visualization component in SET, the SETV. SETV allows analysts to examine the thematic details and corresponding spatial and temporal context and proximity of the events. The foundation of the visual display is the set of semantically related events and the spatial, thematic, and temporal information which define them. To create the visualization, the basic attributes and relationships of these data dimensions (what, when and where) are brought together in a common framework that allows interaction and exploration of their metadata.

The visualization environment consists of a 2D geo-referenced map textured onto the surface of a 3D object. We use the third dimension to visualize the time of the events. The events are connected in space via lines to reveal the sequence of the events in time. There is an event at each end of a line segment. These events are visualized as small spheres and are selectable by the user. Using her virtual laser pointer, a user can select one of these events and then by issuing voice commands the metadata extracted from the ontologies can be presented to her. Examples include playing movie clips, showing digital images, playing audio clips, audio presentation of the date, time, casualties and other information associated to the selected event. Figure 1 shows a map in the virtual environment and how the sequence of events is visualized in space and time.

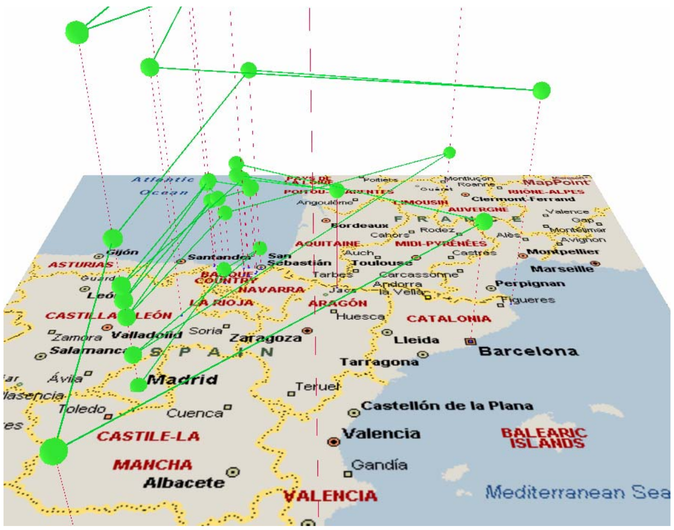

Figure 1. Green line-segments connect consecutive events. Thin vertical red lines connect each event and the place of occurrence onto the map.

From each event, there is a thin perpendicular line (the red lines in figure 1) onto the map showing the place the event happened. The space where the events are visualized over the map is defined by an invisible cube. The events are first sorted based on their time and then they are scaled to occupy the height of the cube or the aquarium as it is defined in [6].

Upon selecting an event, information such as time, date, place, etc, is spoken by the SC's speech synthesizer, which also provides information about the availability of multimedia associated with the selected event. Information about the events, which the speech synthesizer reads to the user, include: the date of the incident, casualties, responsible organization or person(s), attack type, and media of attack. The user can then issue a voice command to the SC's speech recognizer engine; such as "action show media". Movie clips and digital pictures can be played and shown within SETV. Movie clips and digital images are visualized as texture mappings onto 3D shapes in the background as shown in figure 2. Users can stop the performing action by issuing the "cancel" voice command.

Figure 2. Snapshot of SET showing multimedia within SETV

In addition to the user being able to change the orientation and the position of the map, the user can also manipulate the map. Using her laser pointer, the user can zoom-in, zoom-out, pan, and zoom-in in a particular rectangle on the map. At each map manipulation, SETV contacts the Map Renderer (MR) sub-system to render the appropriate map. This functionality is borrowed directly from already available services on the Internet such as Google's maps and Microsoft's MapPoint. We have enhanced this behavior to be used within a synthetic environment.

V. Evaluation Method

To evaluate SET's interface, we performed two experiments: one evaluating the 2D interface (the web client user interface which is part of the Event Data Store (EDS), and two, the 3D interface (the Semantic Event Tracker Visualizer (SETV)). We wanted to find if the two interfaces provide any benefits compared to each other.

Seventeen subjects volunteered to participate in the experiment. The subjects were graduate and undergraduate students. Ten subjects volunteered in the experiment where we evaluated the 2D interface and seven subjects volunteered in the experiment where we evaluated the 3D interface.

Three subjects participating in evaluating the 2D interface could not answer the temporal question (question #2 shown below) properly and we had to terminate the procedure. Fourteen subjects successfully completed the experiment; equally divided between the two experiments.

The subjects had a 5-minute training session to familiarize themselves with the interface (either the 2D or the 3D). First, they were introduced to the user interface. The subjects were given 5 more minutes to practice and become familiar with the user interface.

After the training and the practice sessions, we loaded and visualized the data that included terrorist events in 600km proximity of Zaragoza during the periods of 2000 through 2002; all subjects were aware of the specifics of the dataset we loaded. We then asked the subjects two questions, one after the other, and we timed them for each question. In the analysis, we used the elapsed time from the moment when we asked each question until they provided the answer as the performance measure. The first question was “location” related and the second question was “time” related. The two questions were:

- Question 1 (Q1). What specific pattern do you see in the geographic distribution of the locations of the events? More specifically, where most of the events occur?

- Question 2 (Q2). What specific pattern do you see in the temporal distribution of the events? More specifically, when most of the events occur?

VI. RESULTS

Our hypothesis was that there is a significant difference in the population means of the different levels of our single factor, which was the “interface type” (2D and 3D). We used a between-subject experimental design. Our independent variable was “interface type” and our dependent variable was performance (time to answer each question). We tested the hypothesis by comparing the means of the pooled performance scores using one-way analysis of variance (ANOVA).

We compared the results based on the interface type and we found that in the 3D interface, the subjects could answer the second question faster ($F(1,12)=38.517$, $p<0.001$; (2D: mean=55, standard deviation=19.79) and (3D: mean=7.4, standard deviation=4.43)), and this difference in performance is significant. However, we did not find any significant difference in the scores for the first question ($F(1,12)=0.44$, $p=0.52$; (2D: mean=11, standard deviation=10.65) and (3D: mean=14.43, standard deviation=8.64)).

VII. CONCLUSIONS

This paper presents Semantic Event Tracker, a highly interactive visualization tool for tracking and associating events in a synthetic, multimedia and spatially enriched environment.

Through our experimental results and analyses, we believe that SET could become a viable tool to assists users in tracking and associating events and for decision making. The dynamic nature of SET allows a user to unfold and trace relevant events and processes, and display attributes of events on demand. Events of interest can be selected by their semantic associations, type, time or position. The set of relevant events can then be browsed and examined in a highly interactive environment. SET visualizes spatiotemporal and thematic data alongside related media information such as audio/video clips, digital images, etc. in an integrated environment. SET brings together many technologies such as speech recognition, speech synthesis, virtual reality, Web services, and geographic information system, all working together in harmony, to assist the end-user achieve a better insight on a collection of events.

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