GeoJabber: Finding Significant Analytic Events in Collaborative Visual Analysis Sessions

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ABSTRACT

The integration of a peer-to-peer instant messaging system into visual analytic software allows automatic extraction of significant analytic events, such as inference drawing, causality determination, or hypothesis generation, during the course of an analysis. It does so by examining the textual communications between collaborators and marking those analytic events which are determined to be significant using term extraction and term matching. These events can be used as entry points into the analysis session, as a way to better understand both the subject of analysis (such as a possible Sarin gas attack), the collaborative behavior of the analysts, and patterns of tool use. This approach can potentially make visual analytics more productive through support for sharing fragments of reasoning among analysts. The GeoViz Toolkit introduced here is an open source software project that enables multivariate visual analysis of geospatial data. The open XMPP communication protocol (also known as Jabber) was used in the GeoViz Toolkit software to create a working prototype of a geocollaboration system, by creating extensions to Jabber to support tool state sharing, including geospatial aspects of tool state. Advantages and disadvantages of using XMPP vs. other implementation methods are detailed through a set of examples and discussion of those examples.

KEYWORDS: Collaborative and Distributed Visualization, Human-Computer Interaction, Geographic Visualization, High-dimensional Data, Visualization system architectures, toolkits, and problem-solving environments

1 INTRODUCTION

A recent report by the National Research Council asserts that "enabling collaborative work with geospatial information" is a key research challenge to support in activities in many domains, including homeland security [1]. A scenario that illustrates this would be that in the event of a terrorist attack, multiple people would need to coordinate their response to the attack at the same time. A map interface that supported input from multiple users could be critically important. The unfortunate truth is that current geospatial information technology does not support collaboration between users in different places working on the same problem at the same time. This paper presents a test system that would investigate how to mediate between users who are working on the same geospatial problem in different places.

The core problem that this research attacks is "how can users' actions in maps in different places be coordinated?" The issue is that if multiple users make coordinated changes to the map interface, for example the current extent being viewed, it is potentially disorienting to the map user. Imagine two users simultaneously trying to zoom in on different areas of a map. If the users' maps are fully coordinated in the spatial extent that the maps show, the users might experience frustration and conflict. Two alternative options for mediating the conflict are having persistent settings and to have a selectable history of map extents. The persistent setting approach is to have "Leader" and "Follower" settings on each map. If one user sets his or her map to the "Leader" setting, and the other user sets his or her map to the "Follower" setting, the leaders' map extent would automatically be reflected in the followers map. The alternative, selectable history, method would be to give each user a clickable list of spatial extents, and allow the user to click on them to apply them. These approaches have shown promise in other problem domains [2].

In the remainder of this paper, first the GeoViz Toolkit is introduced, next a typology of what is to be coordinated between users during a collaborative analysis session is introduced, then the GeoJabber implementation is presented, with other implementation alternatives described.

2 THE GEOVIZ TOOLKIT

The GeoViz Toolkit is an Open Source project which enables multivariate exploration of geospatially referenced data sets. One configuration of its user interface can been seen in Figure 1 below.

Figure 1: GeoViz Toolkit Interface

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3 Categories of Coordinated Visual and Numerical Aspects of Data Representation

Here, we take a more detailed look at what coordination is to be done, as opposed to how to do it. All of these event types will be supported by GeoJabber. We do this by first examining previous work in the area, then by going into some more detail about the mechanisms used to implement coordination in the current research, events and event listeners. Additionally, we will examine the rationale and data structures used for different categories of coordinated visual and numerical aspects of data representation.

Identifying the categories of coordination among types of visual and numerical aspects of data representation is a critical task for geographic visualization software for enumerated data. It is related to, but separate from, the task of identifying GIS operations [3, 4], space-time operators [5], and interactivity types in geovisualization [6]. Albrecht provides a set of universal GIS operations, including the following categories of operations: Search, Location Analysis, Terrain Analysis, Distribution/Neighborhood, Spatial Analysis, and Measurements. Crampton offers the following four categories of interaction: (1) with the Data; (2) with the Data Representation; (3) with the Temporal Dimension; and (4) Contextualizing Interaction.

Albrecht's and Crampton's categories, while helpful, are in some aspects orthogonal to the categories of coordination being developed here. For example, coordination itself is considered a Contextualizing Interaction in Crampton's typology, as is having multiple views on the data. Similarly, most of the operations in Albrecht's work are specific to the spatial aspect of the data, aside from the "search" operation, which maps to selection. One of the conceptual bases for Crampton's typology is a single, integrated map visualization component to which other components may be linked. The GeoViz toolkit was developed with the concept of co-equal components, none of which has a central role, except perhaps the coordinator itself. I draw on Crampton's first three categories when defining my own (see below).

More open-ended, and therefore more applicable to the task of defining what categories of coordinated geovisualization are appropriate, is a taxonomy of visualization goals, presented in [7]. These "goals" are categories of visualization strategies, identified as pairs of two categories, an "action" and "data". Types of action include: identify, locate, distinguish, categorize, cluster, rank, compare, associate, and correlate. Types of data include: scalar, nominal, direction, shape, position, spatially extended region, and structure. Thus, highlighting selected observations in a scatterplot would fall under the goal "identify cluster", highlighting in a map would be "identify spatially extended region". What is needed for categories of coordination is closer to the "action" categories, since different visualization components will have different "data" types that they operate upon, for example, the scatterplot and map operate on different sets of data, but may share "action" types.

Keim [8] provides an interesting classification of visual data mining techniques that also has relevance here. He identifies data types (one-dimensional, two-dimensional, multidimensional, text, hierarchies, algorithms), visualization techniques (2D/3D plots, transformed displays, icon-based displays, dense pixel displays, and stacked displays), and interaction techniques (interactive projection, interactive filtering, interactive zooming, interactive distortion, interactive linking and brushing). As candidates for types of coordination, the data types and the interaction techniques are both possibilities, and representatives from both are present in the categorization presented here.

The following are tentatively proposed as primary types of coordinated visual and numerical aspects of data representation: **data**, **display**, and **category**. These are arranged in order of likely dependence in the construction of a geovisualization view. *Data* coordination is the coordination of the set of entities under analysis. Data comes first, because it is the "universe" that all other operations are applied to. Examples of data coordination would be applying the same overall data set to a number of components simultaneously, and extending the data set to include a derived field for each entity. *Display* coordination is the coordination of representation methods. Examples of display coordination would be using the same data-to-display size mappings in multiple components, and applying the same background color in multiple components. Displays follow Data because the user may often wish to vary the symbolization to better explore the data. *Category* coordination is the coordination of divisions (or groupings) in the data. Examples of coordinated categories include linked brushing between components (where categories are "highlighted" and "not highlighted"), and focusing on the same data range in different components. Categories come last because they encompass such transitory operations as which observation is being currently examined by the user. Each of these types represents fundamental operations in geographic visualization that apply to many kinds of visualization components. Each of these may also be expanded into subtypes. Below, the types and some sub-types are expanded upon, and then the current set of events supported in the GeoViz Toolkit is mapped onto these types.

3.1 Data

The "data" type includes events that carry the information that there is a new or different set of data to analyze. This kind of event indicates that the data space being analyzed has been changed. For example, if a spatial data set representing the provinces of Nepal replaces a data set consisting of the states of the United States, this should be communicated to any coordinated components. Extensions to the original data observations, including calculated fields or data linkages, would also be communicated using data type events. Similarly, extensions to variables, such as metadata on the origin and accuracy of different variables, would be communicated with data events.

3.2 Display

If the user has assigned some visual representation to some observations, these should be widely communicated and used. This coordination can enable discovery of spatial patterns based on non-spatial attribute data, and exploration of particular places in attribute data. Symbolization events could include information about many kinds of data to display mappings. Subtypes of symbolization include static visual properties, and dynamic visual properties.

Static visual properties useful for representing data identified by MacEachren [9] include: location, size, crispness, resolution, transparency, color value, color saturation, color hue, texture, orientation, arrangement, and shape. A similar set was parsed by Wilkinson [10], following Bertin [11], into Form (size, shape, rotation), Color (hue, brightness, saturation), Texture (granularity, pattern, orientation), and Optics (blur, transparency). These subtypes (form, color, texture, optics) are a promising avenue to explore for coordinated symbolization.

Dynamic properties include variables applying to whole scenes, and to individual observations. Three "dynamic variables" – scene duration, rate of change between scenes, and scene order – were initially identified by DiBiase et al. [12], to which three more were later added display date, frequency, and synchronization [9]. All of these can also be applied to individual observations as well, as could jitter and "motion paths" [13].

Other important sensory modalities of information representation include sound [14] and touch [15]. Further, data-to-display mappings and coordination of display form (e.g. a change from a choropleth map to a graduated circle map that should be reflected in all maps in a matrix) should be included here.

3.3 Category

Category type operations include many types of sub-setting operations on data sets. These are subdivided into "extent" types of coordination, and "classifying" types of coordination. The extent type includes attribute, spatial, and temporal, as further sub-types. The attribute subtype includes user-driven selections, as well as focusing and indication operations. Classifying includes such potentially coordinated aspects as traditional cartographic classifications, for example, selecting among quantile, equal interval, and minimum variation (optimal) classifications, and more complicated multivariate classifying, such as K-means clustering.

4 GeoJabber

The various operations are realized in the context of collaborative geographic visualization by creating events which encapsulate these operations, and then attaching them to Jabber, also known as XMPP, packets.

Jabber is an open standard for instant messaging [16]. It is based on XML, in that valid XMPP packets are also well-formed XML packets. XMPP specifies an extension mechanism which is used here to attach the visualization events to the XMPP packets. Java objects representing the various visualization aspects are have been marshaled to XML using the Open Source XStream library. This requires writing small adapter classes for each type to be marshaled to XML and back to Java.

An advantage of this approach is that the various components do not need to distinguish between a "normal" event, and one that is from the GeoJabber channel. The GeoViz Toolkit with the GeoJabber tool enabled is shown in Figure 3.

Next, various approaches to collaborative visualization that were evaluated are described, in order of attractiveness, from most suitable to least suitable.

4.1 Jabber (XMPP)

Jabber was the technology selected for implementation. It has the virtue of language and platform independence, and its basis in

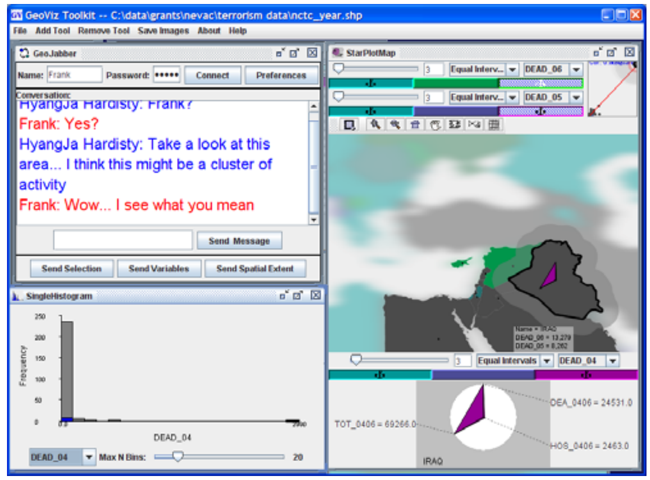


Figure 3: GeoJabber in the GeoViz Toolkit

XML means that it is human-readable. There are many XML transformation and storage routines freely available, which makes it easy to work with. A disadvantage is that XML is verbose: an array which would take four megabytes in binary form might take thirty two megabytes in XML form. Compression can help with this problem, but that makes the XML binary, and if the data structure is large, such as a detailed map of US counties, the data may not fit in main memory.

4.1.1 Jabber packet structure

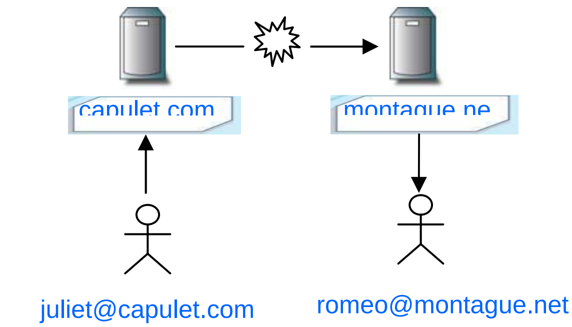
```
<message
    from='juliet@capulet.com'

    to='romeo@montague.net'
        id='message22'>
      <body>
        Wherefore  art  thou,
    Romeo?
     </body>
</message>
```

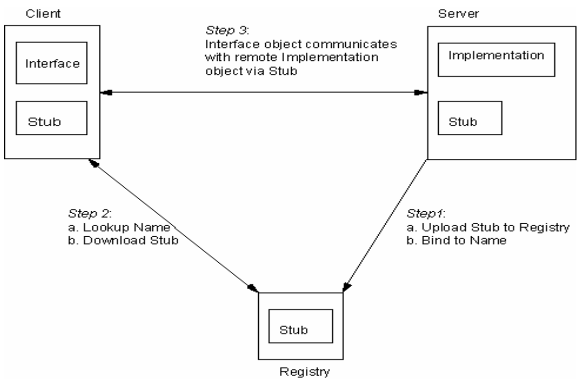
The prototypical Jabber packet structure is shown above.

Note that it is fairly easy to read, even without extensive prior knowldege of Jabber or XML. Server to server communication ish shown in the next figure.

4.2 RMI



RMI was the runner-up implementation strategy. A working prototype was created using RMI, but was abandoned for the following reasons: It is a Java only solution, it is brittle across changes to clients and servers, and it requires a three-tier system of registries, servers, and clients, where each coordinating party has to be both a client and a server. This is too much technical and conceptual overhead for this part of the application.



Other alternatives evaluated for this purpose were JXTA (a peer-to-peer technology developed by Sun Microsystems) and raw sockets. JXTA is interesting but not mature enough for current use. Raw sockets do not support the concept of objects and are thus too low-level.

5 Conclusions

This paper described the GeoViz Toolkit, a typology of the types of operations supported by the Toolkit, and an implementation strategy for using the XMPP standard for same-time collaboration between distributed users. The types of visual operations described will be coordinated over XMPP.

To better serve analysts, practitioners of visual analytics need to better understand how visual analytic tools are used. The field of human-computer interaction (HCI) has approached this problem (in part) by examining human-computer interaction events, such as mouse motion, or tool activation, which are automatically produced during tool use. One limitation of this method has been that it is difficult to extract the meaningful parts of such event streams.

The resulting software can be used as a test bed for experimenting with collaborative functionality in a geospatial context. The peer-to-peer architecture allows the possibility of a secure and extensible system. It is available to users in both source code and executable forms.

References

[1] NRC, *IT Roadmap to a Geospatial Future*: National Academies Press, 2003.

[2] C. Balkanski and M. Hurault-Plantet, "Cooperative requests and replies in a collaborative dialogue model," *International Journal of Human-Computer Studies*, vol. 53, pp. 915-968, Dec 2000.

[3] J. Albrecht and H. Kemppainen, "A Framework for Defining the New ISO Standard for Spatial Operators," *GIS Research UK*, pp. 78-84, 1996.

[4] J. Albrecht, "Geospatial information standards. A comparative study of approaches in the standardisation of geospatial information," *Computers & Geosciences*, vol. 25, pp. 9-24, Feb 1999.

[5] L. Qian, M. Wachowicz, D. Peuquet, and A. MacEachren, "Delineating Operations for Visualization and Analysis for Space-time Data in Gis," in *GIS/LIS '97*, Cincinnati, OH, 1997, pp. 872-877.

[6] J. Crampton, "Interactivity Types in Geographic Visualization," *Cartography and Geographic Information Science*, vol. 29, 2002.

[7] P. Keller and M. Keller, *Visual Cues: Practical Data Visualization*. Los Alamitos, CA: IEEE Computer Society Press, 1992.

[8] D. A. Keim, "Information Visualization and Visual Data Mining," *IEEE Transactions on Visualization and Computer Graphics*, vol. 8, 2002.

[9] A. M. MacEachren, *How Maps Work: Representation, Visualization, and Design*. New York: Guilford Press, 1995.

[10] L. Wilkinson, *The Grammar of Graphics*. New York, NY: Springer-Verlag, 1999.

[11] J. Bertin, *Graphics and Graphic Information Processing*: Springer-Verlag, 1981.

[12] D. DiBiase, A. M. MacEachren, J. B. Krygier, and C. Reeves, "Animation and the role of map design in scientific visualization," *Cartography and Geographic Information Systems*, vol. 19, pp. 201-??, 1992.

[13] C. Ware, *Information Visualization: Perception for Design*. San Diego, CA: Academic Press, 2000.

[14] J. Krygier, "Sound and geographic visualization," in *Visualization in Modern Cartography*, A. MacEachren and D. R. F. Taylor, Eds. New York: Pergamon, 1994, pp. 149-166.

[15] A. Griffin, "Feeling it Out: The Use of Haptic Visualization for Exploratory Geographic Analysis," *Cartographic Perspectives*, vol. 39, pp. 12 - 29, 2000.

[16] S. Chatterjee, T. Abhichandani, H. Q. Li, B. Tulu, and J. Byun, "Instant messaging and presence technologies for college compuses," *Ieee Network*, vol. 19, pp. 4-13, 2005.