Spatiotemporal Mashups: A Survey of Current Tools to Inform Next Generation Crisis Support

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ABSTRACT

Developments in information and communication technology (ICT) have adjusted the opportunities for spatial and temporal representations of data, possibly permitting the simultaneous visualization of how different regions and populations are affected during large-scale emergencies and crises. We surveyed 13 crisis-related mashups to derive some high-level design directions to guide the design and testing of next generation crisis support tools. The current web mashups offer a new way of looking at how crises are spatiotemporally ordered. However, since all technology is constrained by limitations of design choice, examining the limits and possibilities of what current design choices afford can inform attributes of what next generation crisis support tools would require.

Keywords

Crisis informatics, technology design, spatiotemporal data, web mashups.

INTRODUCTION

People use the dimensions of time and space to explain how events develop and how to operate in the world. These dimensions help society organize (Zerubavel, 1981) and coordinate, so that people can, for example, be at work on time or avoid traffic. Disaster researchers and practitioners often use spatial and temporal models (Dynes, 1970; Powell, 1954) to describe and anticipate macro social behavior. These are largely described as the spatial zones of *Impact*, *Fringe*, *Filter*, *Community*, and *Regional* (see Figure 1), and the four major temporal phases of *Preparation*, *Warning*, *Response*, and *Recovery* (with more refinement in some models, see Figure 2). They are useful depictions, and describe critical behaviors made distinct by the suddenness, urgency, and typically geographically bounded impact of large-scale crisis events.

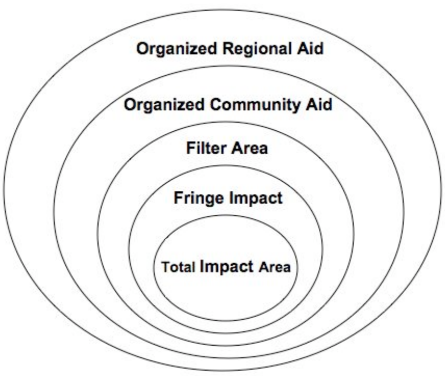


Figure 1: Disasters Zones Adapted from Dynes (1970)

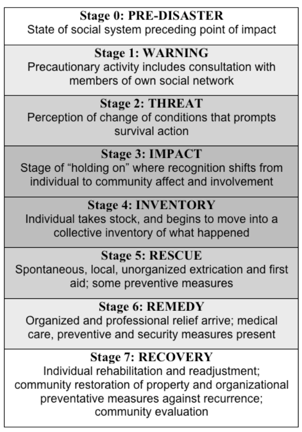


Figure 2: Socio-Temporal Disaster Stages Adapted from Dynes (1970) and Powell (1954)

Temporal and Spatial Descriptions of Disaster Events

Disaster researchers often discuss the temporal and spatial features of crises as occurring in phases and being organized in spatial zones. Powell (1954) created a classification made up of eight temporal stages to illustrate the different social behaviors that take place across time (see Figure 2). Dynes (1970) described the geography of disaster events based on a series of concentric zones (see Figure 1). The center is an area with very severe impact, which is surrounded by a fringe area with significant damage and disruption. Aid from distant communities pass through the regional and adjacent filter zones to provide resources to the impact areas. As Stoddard (1968) points out, time-and-space models are important methodological disaster research tools. The codification and classification efforts of these models are useful heuristic devices for organizing, describing, and explaining data, since the different disaster phases and zones represent different types of individual and group behavior (Stoddard, 1968; Neal, 1997). In our own earlier work, we relied on these macro social descriptions of spatial and temporal ordering to help frame a larger set of imminent changes arising from pervasive information and communications technology (ICT) diffusion (Palen and Liu, 2007).

Disasters as Processual Phenomena

In practice, of course, and depending on the nature of the event, spatial zones and temporal phases are not discrete (Neal, 1997). Populations are differently affected by crises at different stages of response and recovery. For example, the logistical activities that are supported by the *Filter* zone change over time as recovery ensues. These models presented in the previous section are meant to serve as helpful categorizations to support planning and explain social behavior after the fact; they are not accurate definitions of what can or should be happening when a crisis unfolds. As such, some disaster scholars have emphasized that we need to more deeply attach such conceptualizations of large-scale crises to matters of process.

Disaster researchers and other crisis-related scholars have since reconsidered and reconceptualized these categorizations to represent the more complex phenomena that underlie them. Neal (1997), for example, critiqued these earlier models, claiming that disaster phases are multidimensional and should reflect social rather than objective time, and include multiple perceptions of the event from different stakeholders. Oliver-Smith (2001) argues that disasters should more accurately be viewed as processual phenomena with historically produced patterns of vulnerability embedded within them. He emphasizes that “part of the problem is that disaster is often considered an event rather than a process” (p. 23); we must view disasters as “multidimentional because they are both physical and social event/processes…[that are] socially constructed and experienced differently by different groups and individuals, generating multiple interpretations of an event/process” (p. 25). This processual view represents a historical shift in the spatiotemporal dimensions of crises, one that coincides with other changes to conceptualizations of space and time.

Space and Time in a Networked Society

Though the discussion here is particular to emergency and disasters, others have made observations about social organization and the blending dimensions of time and space in a networked society. The sociologist Castells (1996) explains that the spatial and temporal patterning of social practices is changing as we shift towards more network-based communications. As our society becomes increasingly networked, operation within space and time as they relate to social coordination are tied to the opportunities and limitations of ICT.

Castells (1996) discusses how the emergence of digitally supported social interaction across multiple places occurs in “the space of flows”, and is shaped by a constellation of information, people, and artifacts brought together in new ways and under new circumstances. Specifically, he proposes “that there is a new spatial form characteristic of social practices that dominate and shape the network society” and where “the space of flows is the material organization of time-sharing social practices ” (p. 412). In addition, “timeless time” in the networked society is the “transformation of human time under the new social socio-technical context” (p. 430) that has a “mix of tenses” and exists in two different forms: simultaneity and timelessness. ICTs facilitate simultaneity of time through instant information exchange, live reporting, and real-time updates thus providing “a sense of immediacy that conquers time barriers” (p. 461). However, timelessness occurs when times from different media are mixed together through the same channel of information creating “a temporal collage, where not only genres are mixed, but their timing becomes synchronous in a flat horizon, with no beginning, no end, no sequence” (p. 462). For Castells, the blending of time and place occurs when “the multiple space of places, scattered, fragmented, and disconnected, displays diverse temporalities” (p. 467).

Representations of Space and Time Using ICT

ICT is opening doors for new ways of thinking about crisis information in terms of developing socio-technical solutions that support these complex spatial and temporal conceptualizations. In the networked world that Castells (1996) describes, we are compelled to consider the socio-temporal attributes of social organization in new ways that are akin to the multiple, overlapping streams of social activity and macro-level processes of disasters that Oliver-Smith (2001) describes.

But while networking changes the spatiotemporality of our interactions, it itself imposes yet a new social ordering, and one dictated by the constraints and demands of programming machines. We must be careful not to assume that technology can automatically support process and "flows." In fact, it can both simultaneously open up how we think about the ordering of crisis events—primarily because it allows certain kinds of spatial and temporal information to become more visible—as well as inadvertently constrain perceived social ordering depending on design choices made to represent the information. There is much to be learned about how ICT supports crisis information sharing for events that have particular kinds of spatial and temporal attributes. Since spatial and temporal attributes are an important aspect of crisis information (e.g., "the fire line is at <coordinates> at time 12:20 EST on 27 October, 2008"), and because people—in real-time—have different relationships to the crisis, we must address how such information can affect social behavior and support understanding of crisis situations possibly before, during and after such events.

The recent developments of crisis-related web mashups that have strong spatial and temporal components have the potential to possibly challenge or extend these space-and-time models to inform the technology design of crisis support tools. Among the many Web 2.0 technologies now available, data mashups illustrate the Web 2.0 culture of data reuse. In web development, mashups are web applications that combine data and/or functionality from one or more existing third party sources into a single integrated tool. The purpose of the mashup may be to provide a new service, to present information in a new way, or to create a new user experience by producing rich datasets. Around twenty percent of the mashups on ProgrammableWeb[1] are tagged as maps and typically use the Google Maps API. Zang et al. (2008) investigated the experiences of mashup developers pointing out that map mashups are the most common because they are "the most visual and adaptable of the mashup options" (p. 3175). Wong and Hong (2008) conducted a survey of mashup patterns "to help drive the development of mashup tools to support specific patterns" (p. 35).

In this paper, we use recent crisis-related mashups to derive high-level design directions to guide the design and testing of next generation crisis support tools. Based on our survey of these mashups, we consider how the design choices of features address the complexity of spatiotemporality by teasing apart and newly representing spatial and temporal features of crisis data.

ANALYSIS OF DESIGN AFFORDANCE FROM A SURVEY OF EXISTING CRISIS-RELATED MASHUPS

In this section, we examine the design choices of 13 crisis-related mashups that exhibited strong spatiotemporal features using inspection methods—that is, without users, and with a first order goal of isolating critical design-use relationships upon which additional user-based testing with more advanced designs could investigate in the future. The final Discussion section presents three design directions for future crisis support technology.

[1] http://www.programmableweb.com/mashups

Ushahidi

The inspiration for examining spatiotemporal mashups began with the Ushahidi[2] website. Ushahidi—which means "testimony" in Swahili—was first developed to map reports of violence by citizen journalists in Kenya after the 2007 elections[3] (Meier and Brodock, 2008). More recently, Al Jazeera[4] adapted Ushahidi and incorporated Twitter to provide reports related to the 2008-2009 Israel-Gaza conflict. Their goal is to create a web platform for gathering and mapping real-time reports from the general public via mobile phone, email, and the web. They hope that publicly visualizing this information will mobilize people to assist members of the public, mobilize governments to react, and inform people about how they can assist through an ongoing dialogue.

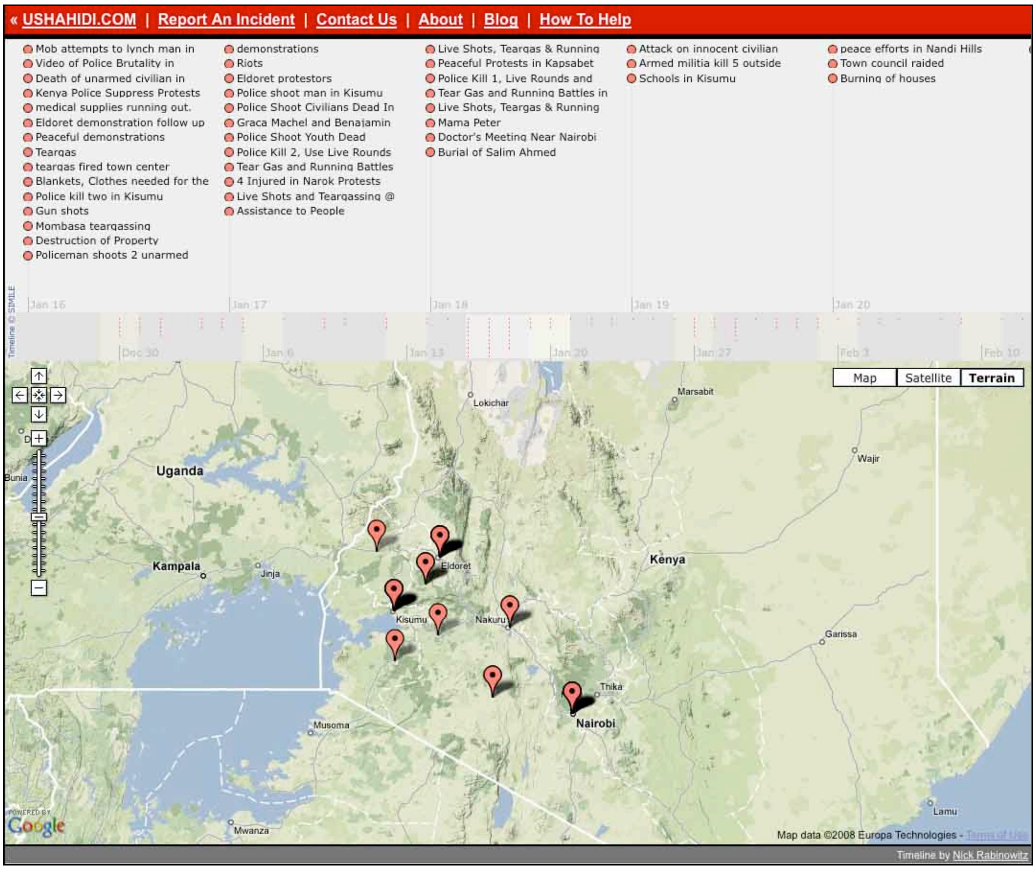


Figure 3: Ushahidi Kenya Map-Timeline Mashup

The Ushahidi mashup uses the Google Map API[5] and the Simile Timeline API[6], which allows a more seamless way of visualizing and synchronizing temporal information in a spatial context (see Figure 3). This mashup contains a never-ending timeline interface superimposed on a digital map showing icons that only appear at the chosen timeframe. It allows the user to dynamically select the time interval with a slider feature on the Simile timeline thus only showing data points within this timeframe on the map view. However, the first view of the Ushahidi mashups focuses more on the map but with temporal information hidden in the pop-up box for each icon on the map (see Figure 4). Yet the other view that uses Simile shown in Figure 5 visually shows on the bottom timeline how many of the reports were sent starting December 30, 2007, peaking on January 16, 2008, and tapering off around February 16. In Figure 6, you can visually see that many reports are along the Gaza Strip accurately corresponding to the recent 2008-2009 Hamas-Israel conflict in Gaza, where bigger icons indicate a higher concentration of reports. In Figure 4 on the upper right side and in Figure 6 on the right side, the different colors, symbols, and sizes of the icons on the map indicate the type of report that citizens are providing.

[2] http://www.ushahidi.com/
[3] http://legacy.ushahidi.com/
[4] http://labs.aljazeera.net/warongaza/
[5] http://code.google.com/apis/maps/
[6] http://simile.mit.edu/timeline/

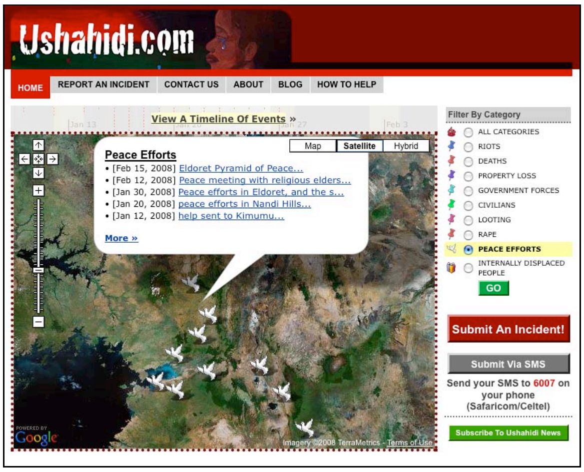


Figure 4: Ushahidi Kenya Map View Efforts

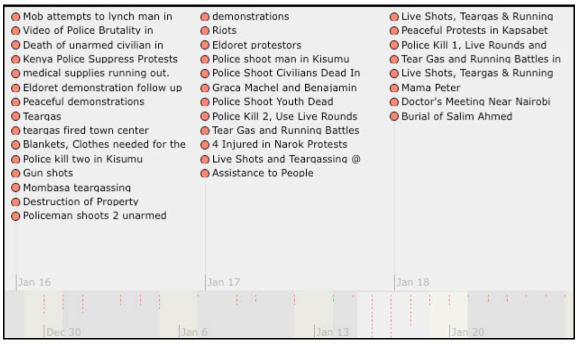


Figure 5: Ushahidi Kenya Timeline

Figure 6: Ushahidi Al Jazeera Mashup

Earthquake Mashups

Earthquake mashups have also been created to visualize different types of spatial and temporal data. The Live Earthquake Mashup[7] also uses Google Maps and the Simile Timeline APIs; however, this mashup only displays earthquake information for the past seven days (see Figure 7). This mashup allows the user to switch between three data sources. The size of the icon corresponds to the earthquake's magnitude; whereas, the darker shaded icons indicate more recent earthquakes. Spatial trends based on the concentration of icons in specific locations may also indicate geographical vulnerabilities due to geological faults or other causes of earthquakes.

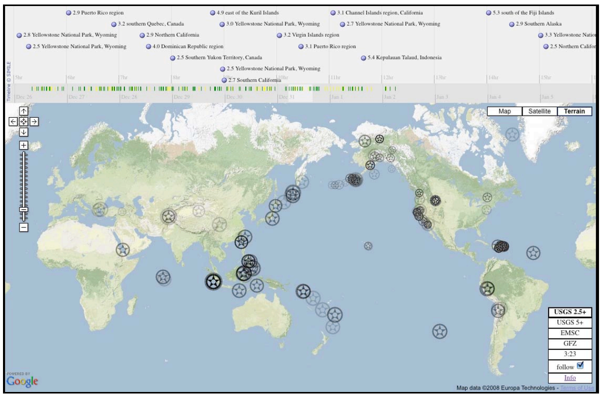


Figure 7: Live Earthquake Mashup

The Earthquakes in the Last Week[8] mashup also shows recent earthquake activity. However, the temporal information is hidden in the pop-up boxes for each icon on the map. The mashup is therefore more oriented toward browsing earthquake activity by location on a global scale, illustrating the high activity around the Pacific Rim (see Figure 8). This mashup also uses colored icons to indicate Richter magnitudes (see icon legend in Figure 8).

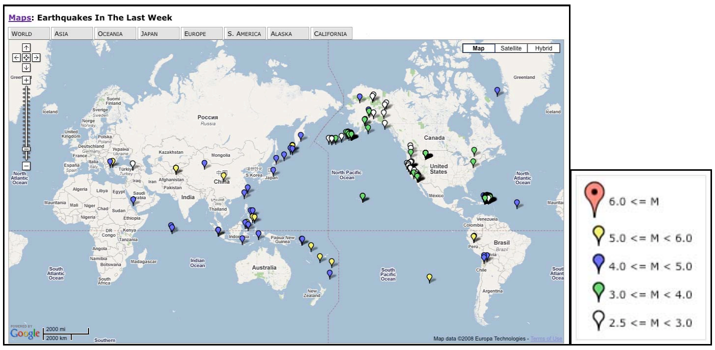
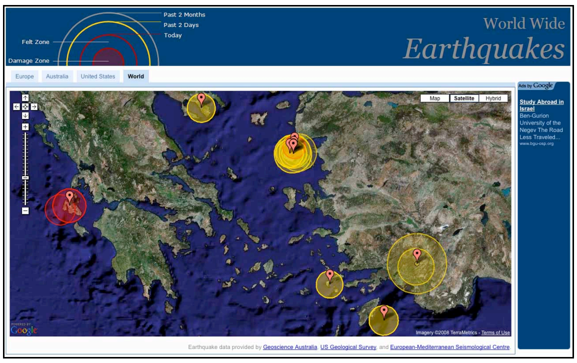


Figure 8: Earthquake Mashup in the Last Week and Icon Legend

The Earthquake![9] mashup also uses Google Maps to show recent earthquake activity as far back as two months ago. Instead of different colored icons, this mashup uses concentric circles around the marker on the map (see Figure 9). The color and size of the concentric circles indicate the quakes occurrence and the felt impact zone (see Figure 10).



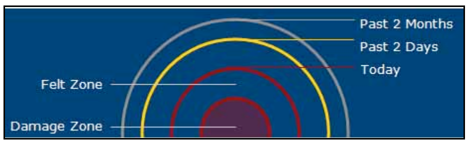


Figure 9: Earthquake! Mashup

Figure 10: Earthquke! Icon Legend

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[7] http://www.oe-files.de/gmaps/eqmashup.html
[8] http://earthquakes.tafoni.net/
[9] http://earthquake.googlemashups.com/

2007 Southern California Wildfires

In response to the 2007 Southern California wildfires, the 2007 San Diego County Fires – KPBS Online[10] mashup in Figure 11 created by the local news organization KPBS was the most notable and most widely discussed in the media. It was first created on October 21, 2007 and was last updated on November 17, 2007. All the icons on the left side of the mashup appear in reverse chronological order. Each icon was updated to provide real-time updates, but this meant deleting old information to provide the most recent information. This is why Figure 11, the most current view of the mashup, shows the current or last updated status of the 2007 wildfires. Previous screenshots of this mashup illustrate the map during an earlier state (see Figure 12). The Fire Map Legend (see icon legend in Figure 11) also provides clues as to the other types of icons that no longer appear in the current view of the mashup. Although it is now difficult after the fact to understand how the events unfolded, this mashup provided timely and frequent updates making it "an essential and valuable resource during the fire," according to one commenter of this mashup[12].

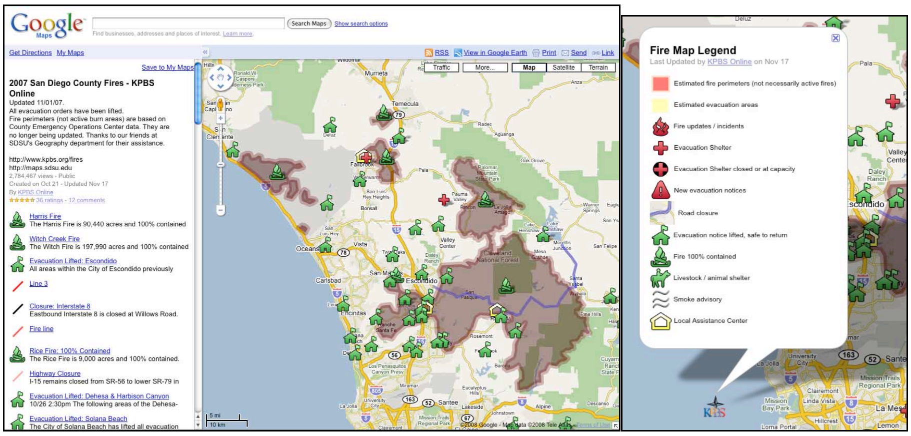

Figure 11: 2007 Southern California Wildfires KPBS Mashup and Icon Legend

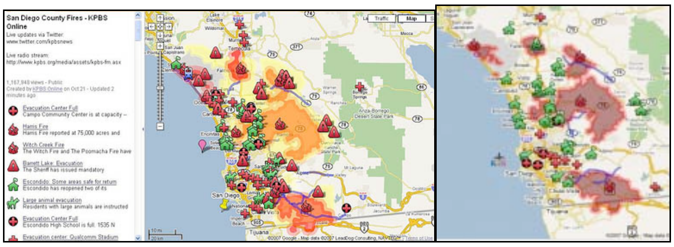

Figure 12: 2007 Southern California Wildfires Earlier KPBS Mashups

2008 Southern California Wildfires

Similarly, in response to the Southern California wildfires in 2008, the Los Angeles Times created a Google Map called Southern California Wildfires.[11] It was created on November 16, 2008 and was last updated on November 18, 2008. Every single icon created in this mashup appears on the left side of the map and are listed in chronological order, allowing the viewer to see when information was updated (see Figure 13). By browsing through the different icons chronologically, we were able to reconstruct how this mashup changed over time from November 16 to 17, 2008 (see Figure 14).

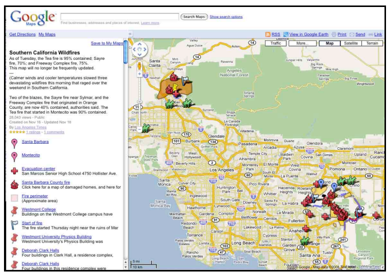

Figure 13: 2008 Southern California Wildfires LA Times Mashup

[10] http://maps.google.com/maps/ms?msa=0&msid=114250687465160386813.00043d08ac31fe3357571 or http://tinyurl.com/8xjwto

[11] http://maps.google.com/maps/ms?ie=UTF8&hl=en&oe=UTF8&msa=0&msid=117631292961056724014.00045bd85c715c6344c7e or http://tinyurl.com/7wrz4o

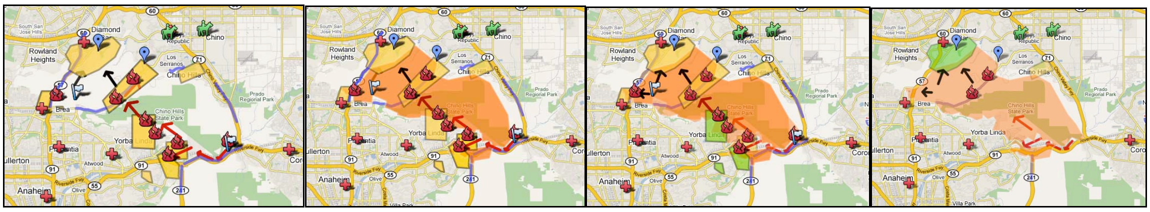

Figure 14: 2008 Southern California Wildfires LA Times Mashup from November 16 to 17

Another mashup created for the 2008 wildfires used Twitter[12], a multi-platform micro-blogging service, to get live updates from people on the ground. Virender Ajmani created a mashup called Los Angeles Fire TWEETS[13], which displayed real-time "tweets" containing the word "fire" that appear within 100 miles radius of Los Angeles (see Figure 15). Since this mashup was created on November 16, 2008 during the wildfires, most of the displayed tweets pertained to the wildfires. Given that the mashup is still active, its current activity displays tweets that often have little to do with wildfires (because "fire" is still a commonly used word). However, since this mashup is already set up, it could be immediately used for future fires in the Los Angeles region. This mashup only displays no more than a day's worth of tweets to keep the data fresh, doing so in reverse chronological order.

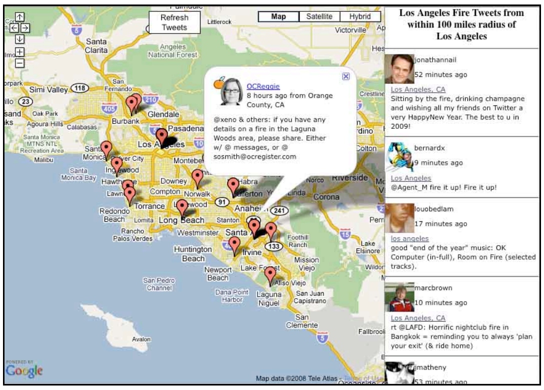

Figure 15: Los Angeles Fire TWEETS Mashup

2008 Mumbai Terrorist Attacks

The Mumbai terrorist attacks started on November 26 and ended on November 29, 2008 taking place in eleven locations across the city of Mumbai, India. One mashup created on December 1, 2008 by "Rakf1" was called the Mumbai Terror Attack Timeline[14] and incorporated information from the 2008 Mumbai attacks Wikipedia article.[15] The timeline appears on the left side of the mashup depicting when each of the eleven locations was attacked. When scrolling over each cell within the timeline, a corresponding pop-up box appears, providing text and/or image-based details of what happened in that location (see Figure 16).

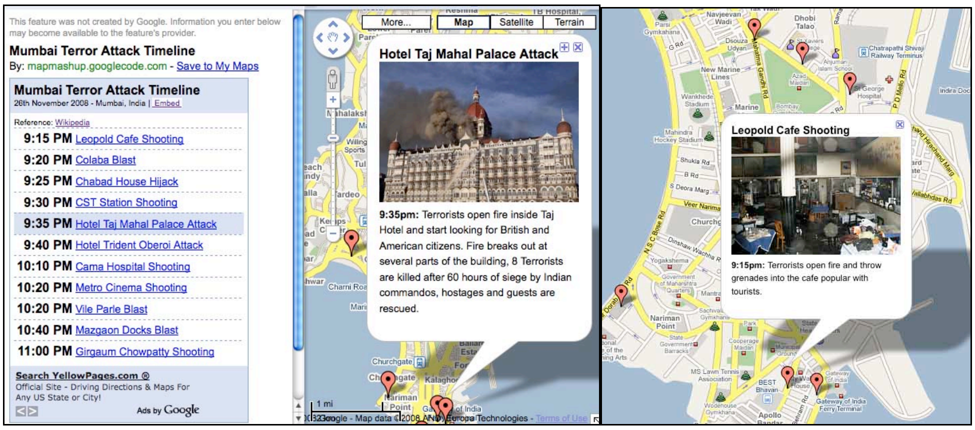

Figure 16: Mumbai Terror Attack Timeline Mashup and Details in Pop-Up Boxes

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[12] http://twitter.com/
[13] http://www.mibazaar.com/lafires.php
[14]http://maps.google.com/maps/mpl?moduleurl=http://mapmashup.googlecode.com/svn/current/mumbaiterror_mapplet.xml or http://tinyurl.com/7aszrm
[15] http://en.wikipedia.org/wiki/November_2008_Mumbai_attacks

During the attacks, "Omar C." created the Map of Mumbai Attacks[16] on November 26, 2008, which was last updated on December 3, 2008. This mashup used data from Al Jazeera English, Google, and Twitter, plotting them on a Google map (see Figure 17). This was a highly detailed mashup, providing real-time updates from news organizations and citizen journalists. Each icon that was created appears on the left side of the mashup; however, they do not appear in chronological order, and the pop-up boxes mostly provided dates without timestamps.

Figure 17: Map Of Mumbai Attacks by Omar C

School Shootings

Virender Ajmani also created a mashup[17] indicating when and where school shootings have taken place worldwide since 1996. The original source of this data is the "Time Line of Recent Worldwide School Shootings" from InfoPlease.com as well as other sources. This mashup provides a numbered list of the 57 shootings in the legend on the left side of the mashup in reverse chronological order with "1" being the most recent shooting with the corresponding number of the shooting appearing in the icon on the map (see Figure 18).

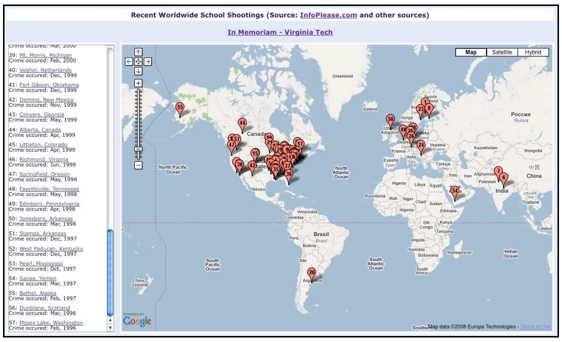

Figure 18: Recent Worldwide School Shootings

Rising Sea Level

Another mashup created by Mibazaar is one that indicates the impact of climate induced sea level rise on particular coastal cities in the United States.[18] This mashup uses data from the *Coastal Impact Study: Nation Under Siege* study conducted by Architecture 2030. This data consists of the flood maps for 31 US coastal cities that were superimposed over Google Earth satellite images to illustrate in detail where floods would occur if the sea level rises. The mashup (see Figure 19) provides an alphabetical list of the coastal cities on the left side of the mashup, which links to the icons on the map with each pop-up box showing flood map images specific to each location. The temporal aspect of this mashup is quite different from the previous mashups in that it shows predictions of the future using visual data. In the case of New Orleans, Louisiana as shown in Figure 19, the user can see satellite imagery of New Orleans in the present day and what it might look like after around one-meter of sea level rise in the future.

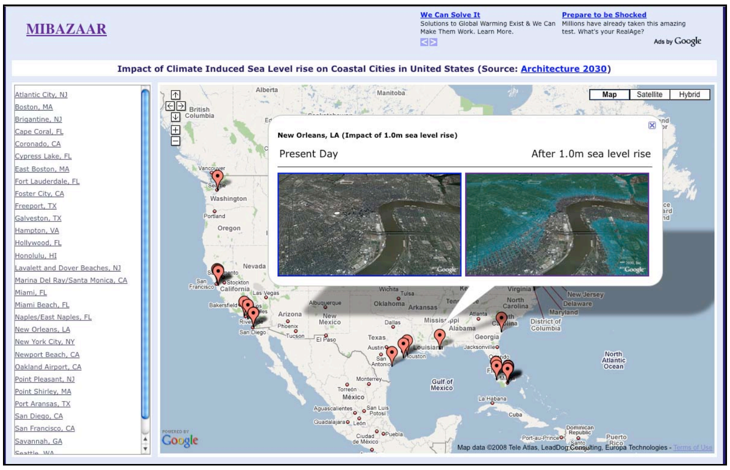

Figure 19: Impact of Climate Induced Sea Level Rise on Coastal Cities in United States, Example of New Orleans

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[16] http://maps.google.com/maps/ms?ie=UTF8&hl=en&msa=0&msid=105055855763538009401.00045c9d8b16af3ad1008&ll=19.011489,72.836609&spn=0.333034,0.4422&z=11 or http://tinyurl.com/8dewol

[17] http://www.mibazaar.com/schoolshootings/

[18] http://www.mibazaar.com/nationundersiege/

AlertMap of Worldwide Emergencies and Disasters

The last mashup we discuss here is a data-rich mashup called the Havaria Information Service – AlertMap[19] by the RSOE EDIS Emergency and Disaster Information Service. It combines over 200 sources of information related to severe weather conditions, biohazard threats, and seismic information into a single geographical representation through a map interface. The mashup provides real-time updates with animated circular icons showing the most recent activity (see Figure 20), but it also shows current emergencies, short-time events (e.g., vehicle accidents, volcano eruptions, extreme weather, flash floods), and long-time or rolling events (e.g., biological hazard, epidemic, volcano activity). The metadata for each of these events always contain temporal (date/time) and spatial (country/county/state/city) information. There are also over 60 different icons. Spatial trends often appear when there is a high concentration of similar icons at a particular location (see, for example, the many earthquakes occurring in and around Greece in early January 2009 in Figure 21).

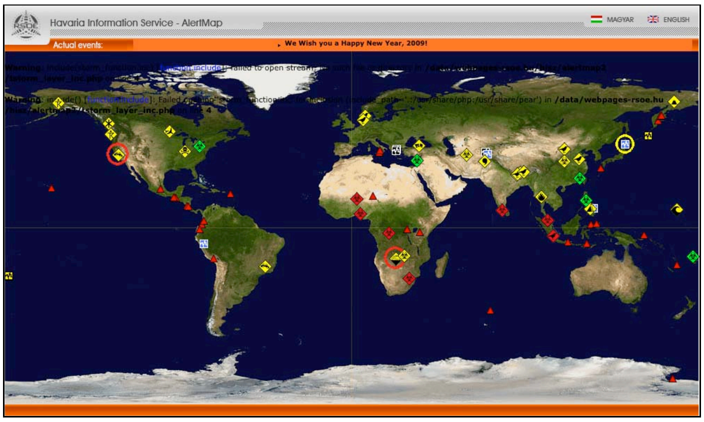

Figure 20: Havaria Information Service – AlertMap

Figure 21: Havaria Information Service - AlertMap Showing Earthquakes in Greece

DESIGN DIRECTIONS

Our analysis of crisis-related mashups depicting spatiotemporal features suggests a set of design directions to guide the technology design and user testing of next generation crisis support tools. Although we did not comprehensively examine all the spatiotemporal mashups created around crises, we did choose mashups that show particular instances of what certain design features may afford. In this section, we discuss three summative design directions that explain how design choices afford different kinds of user interaction and visualizations of the spatiotemporal data.

Using Temporal Data to Communicate Different Levels of Knowledge Granularity

Simultaneously displaying certain kinds of data temporally through a map interface can provide rich visualizations. To draw from Castells' work—and make it prescriptive, if we may—visualizing temporal data spatially can describe "diverse temporalities mixing tenses into a temporal collage." The Ushahidi mashups may be the leading exemplar of illustrating this temporal collage. Though these mashups provided instant, real-time information, the data were also preserved chronologically, allowing users to view the crisis at a macro temporal level, particularly through the timeline on the bottom seen in Figure 5. For instance, simultaneously displaying multiple wildfires that have occurred in the past could provide a macro temporal level understanding of wildfires in particular regions, though a user's need to examine the recent past (say the past year) from the more distant past (say over the past 25 years) should result in different portrayals of the data. However, in the Ushahidi map view in Figure 4 and the Al Jazeera mashup in Figure 6, the temporal metadata is hidden and much less fine grained in the pop-up boxes, thus making it much more difficult to browse temporally. The key design feature here is how the timeline allows the user to replay data backwards and forwards in time to suit different user needs all through the same interface, creating this simultaneity of real-time updates. Still, the difficulty with the Ushahidi interface is that if too many reports are submitted for the same place and/or at the same time, it could render the mashup useless through the chaotic clutter of information.

[19] http://hisz.rsoe.hu/alertmap/

Although the current use of these mashups only focus on preserving real-time reports that become part of the past, the never-ending timeline makes it possible to also submit an incident projected into the future. Some real-time updates will provide news about locations that may be potentially threatened from hazards that have a protracted warning period, as in the case of wildfires and hurricanes; however, this information is usually more helpful in the immediate future. Yet, the long-term or rolling events displayed in the AlertMap (Figure 20) have the potential to provide forewarning information of location-based risks. Similarly, the sea level rise mashup provides predictions about what could happen in certain places to forewarn the need for preparation and mitigation efforts. Other events that could appear on these mashups are crisis-related anniversaries that are planned for learning how to engage in mitigation efforts to prepare for potential related crises. Planting these seeds of an imagined future visibly on a map and in a timeline might create the potential for preparatory action. Although externalizing these future intentions could be both advantageous (strengthening community resilience) and disadvantageous (endangering police operations in terrorist attacks), it is still important to note the potential power in visualizing the past, present, and future simultaneously.

Learning from the Past through the Preservation of Spatiotemporal Information Flows

Preserving spatiotemporal updates also opens up the possibility to learn how certain flows of information, people, and resources at certain times and/or places can inform current and future crisis response and management. Often these spatiotemporal mashups are created with the intention of providing real-time, current updates useful during the immediate pre- and post-impact period. With this intention, the design choices in the earthquake mashups, the 2007 wildfire mashup, the Mumbai mashup using Twitter and other sources, and the AlertMap resulted in time-sensitive information that disappears over time. However, if the traces of all reported activities were preserved—and in a different visualization—this could support investigative, forensic and heritage-preserving efforts.

Given that many of these mashups were created using the Google Map Creator interface, this tool makes it difficult to preserve spatiotemporal metadata when a user simultaneously wants to provide real-time updates. This was evident in the KPBS mashup where the creator chose to update the icons rather than create a new icon, thus deleting the old news. It is now difficult to understand how this mashup was annotated and changed over time. It might be no surprise then that a year later the LA Times wildfire mashup preserved each icon creation on the left side of the map while still providing the most recent updates in the freshest view of the map. Moreover, in the case of the wildfire mashups, past spatiotemporal data of these wildfires can inform future vulnerabilities in these same regions. That is to say, if a new regional fire in Southern California were to occur again, the geographical vulnerabilities would be different from the fires in 2007 and 2008, since the areas that have already burned out are less at risk while other areas may be more at risk because of the way the wildfires previously affected this region. Therefore, as a design choice, it may be helpful to have the option to see spatiotemporal data from past crises to inform current or future crises taking place in the same region. More specifically, this design direction emphasizes externalizing the relationships between or the "flows" of information, people, and resources for particular crises. Design choices that allow the preservation of and easy accessibility to historic data not only can help us learn from past practices but also inform us of geographical vulnerabilities.

Recognizing Geographical Vulnerabilities with Spatiotemporal Data

Temporal trends are particularly important for seasonal hazards, but when viewing temporal trends spatially, the geographical vulnerabilities become more apparent. Spatial trends provide visual indications of which places are at risk based on past history and current circumstances. For example, the clustering and patterning of icons in the AlertMap and the earthquake mashups provide visual clues of geographical vulnerabilities. Some mashups specifically chose certain design features to highlight known geographical vulnerabilities because of past historical crises and scientific predictions. For instance, the Earthquake Mashup in the Last Week (Figure 8) provides continent-based views of the map but creates specialized ones for the earthquake prone regions of Japan, Alaska, and California. Also, in the sea level rise mashup, 31 densely populated US coastal cities were specifically chosen to illustrate risks for flooding. Each of these mashups highlighted geographical vulnerabilities using different design features, with multidimensional or dynamic icons seeming to be more illustrative at-a-glance. In the Earthquake! mashup, each icon changed over time to depict the changing spatial zones and temporal phases in a simultaneous way; whereas, in the Live Earthquake Map mashup, the icon size is based on the magnitude but the icon becomes more transparent as it gets older. The Al Jazeera mashup used a certain color to indicate the type of report but the icon size changed based on the number of similar reports at that particular location and depending on what zoom level the user is in. This design direction emphasizes externalizing which locations may be vulnerable based on past crises. This may be determined based on geological, scientific, and/or socio-behavioral data. This is a critical area for usability research, with this preliminary design survey providing the basis for determining what kind of features to investigate.

CONCLUSION

Current generation crisis support tools, like web mashups, offer a new way to visualize spatiotemporal data and social organization during crises, and they can also work as design probes for thinking about new and better ways of depicting such activity for future events. Based on our design analysis of 13 crisis-related mashups exhibiting strong spatial and temporal features, we consider how design decisions have the potential to elaborate our understanding and even change our conceptions about how crises transpire. We used current crisis mashups to derive improvements and directions for future design that isolate features of spatiotemporal data presentation. We have considered how certain design choices afford different forms of interaction, though we note that certain design choices may be more appropriate for certain hazards than others depending on what types of attributes need to be depicted. As technology designers, we have the opportunity to consider how to represent spatiotemporal data, and how it might be useful for different stakeholders. We hope our paper provides useful design directions to guide technology design and user testing for next generation crisis support tools.

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REFERENCES

1. Castells, M. (1996) The Information Age: Economy, Society and Culture: The Rise of the Network Society, Volume 1, Blackwell, Cambridge, MA.
2. Dynes, R. R. (1970) Organized Behavior in Disaster, Heath, Lexington, MA.
3. Fritz, C. E. (1961) Disasters, *Contemporary Social Problems*, (Eds) R. K. Merton and R. A. Nisbet, 156-191, Harcourt, New York.
4. Meier, P. and Brodock, K. (2008) Crisis Mapping Kenya's Election Violence: Comparing Mainstream News, Citizen Journalism and Ushahidi. Manuscript from the Harvard Humanitarian Initiative, Harvard University, Boston. <http://irevolution.wordpress.com/2008/10/23/mapping-kenyas-election-violence>
5. Neal, D. M. (1997) Reconsidering the Phases of Disaster, *International Journal of Mass Emergencies and Disasters*, 15, 2, 239-264.
6. Oliver-Smith, A. (2001) Theorizing Disasters: Nature, Power, and Culture, *Catastrophe & Culture: The Anthropology of Disaster*, (Eds.) S. M. Hoffman and A. Oliver-Smith, 3-22, School of American Research Press, Santa Fe, NM.
7. Palen, L. and Liu, S. B. (2007) Citizen Communications in Crisis: Anticipating a Future of ICT-Supported Participation, *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems CHI '07*, San Jose, CA. ACM, New York, NY, 727-736.
8. Powell, J. (1954) An Introduction to the Natural History of Disaster, University of MD Disaster Research Project, College Park, MD.
9. Stoddard, E. R. (1968) Conceptual Models of Human Behavior in Disaster,Texas Western Press, El Paso.
10. Wong, J. and Hong, J. (2008) What Do We "Mashup" When We Make Mashups?, *Proceedings of the 4th International Workshop on End-User Software Engineering WEUSE '08*, Leipzig, Germany. '08. ACM, New York, NY, 35-39.
11. Zang, N., Rosson, M., and Nasser, V. (2008) Mashups: Who? What? Why?, *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems Extended Abstracts CHI '08*, Florence, Italy. ACM, New York, NY, 3171-3176.
12. Zerubavel, E. (1981) Hidden Rhythms: Schedules and Calendars in Social Life, University of Chicago Press, Chicago, IL.