Framing the design space for novel crisis-related mashups: the eStoryS example

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ABSTRACT

Web 2.0 can be viewed as a platform where users can develop their own web applications. It is also characterized by a vast amount of user-generated contents presenting spatial and temporal components, by means of associated metadata. These metadata has been successfully exploited to generate map-based mashups (web applications gathering data from different sources) facing different kind of crisis situations, ranging from natural disasters (earthquakes, wildfires, floods...) to human-made disasters (terrorist attacks, school shootings, conflicts...). The social and collaborative dimensions of the Web 2.0 can be also exploited for managing crisis-related information. We present here a survey of current crisis-related mashups we employed to extract design dimensions and provide a conceptual framework that can be used: *a)* to understand current systems and; *b)* to design next generation of crisis-related mashups. We propose the eStoryS system as an example of application developed following the design principles presented in this paper. On the basis of our analysis, we believe that the design dimensions posited here provide useful insights for the design of novel web mashups in the emergency management domain.

Keywords

Web mashups, crisis informatics, collaboration tools, georeferenced information

INTRODUCTION

The Web 2.0 platform is mainly characterized by the availability of a vast amount of user-generated data. In particular, during crisis management activities data from heterogeneous sources is generated on the web: pictorial and video feeds, news reports, emails and text messages. Most of these data expose geospatial information such as: associated metadata (i.e. latitude and longitude), or implicit location references (i.e. the name of a place in a news report). Moreover, temporal information associated to content (i.e. the date a picture was taken) might also be available.

We think that there are many media contents available on the web through different social networks and collaboration systems which are not well-integrated to provide users with an overall view of temporal- and geo(spatial)-referenced information during emergency situations. Temporal- and geo-referenced information is crucial for a rapid understanding of the emergency status, sorting out the recovery plans, providing local information about damages, etc. Therefore, specific tools are required to manage the integration of different contents on a map. But space and time are not the only components to take into account in the design of crisis-related mashups. We refer to a mashup as a Web application that combines data or functionalities from different sources or services into a single integrated tool (Zang and Rosson 2008). A disaster is a multidimensional process physically and socially experienced and, therefore, there are different interpretations depending on the goals or expertise of each person (Oliver-Smith, 2006). Consequently, tools for searching, visualizing, reporting and exploring in different ways information placed on maps are required. Such tools should exploit the features of Web 2.0 paradigm. As an example, useful information can be also retrieved from the analysis of social practices and collaborative interactions among users through metadata.

Our aim in this work is to point out dimensions to guide the design of next-generation crisis-related web mashups. We framed the design space of such applications by analyzing a set of current mashup systems available on the web. We restricted our classification to map-based mashup systems, because we think that,

Reviewing Statement: This paper has been fully double blind peer reviewed.

during an emergency, the spatial dimension is very relevant. Liu and Palen (2009) analyzed the implications of spatial and temporal components in current crisis-related mashups, presenting some considerations as well as high-level design directions. We moved a step forward here by defining a general framework considering further aspects of data available on the Web (besides spatial and temporal features). For example we considered the intrinsic nature of the environment where such applications are developed (Web 2.0), its social and collaborative dynamics and the role of such interactions in generating chronicles or narratives about an emergency situation. Our study also framed the design space with respect to the functionalities a mashup must exhibit to manage crisis-related information, considering such functionalities strictly related to corresponding data properties (metadata). In fact we present a system called eStoryS (emergency Storyboard System) as a mashup developed by using the design space we describe in this paper.

Web 2.0 in emergency management

During a crisis situation it is possible to take advantage of the Web platform and related technologies. Thanks to new Web programming paradigms and techniques, in fact, it is possible (in a short amount of time) to create applications collecting information on the status of an emergency situation (damaged buildings, people got wounded, etc.), which can be distributed to a very wide audience and without requiring high technical skills.

The most common type of on-line activity during an emergency consists of finding and sharing information about personal properties, relatives and friends' safety and sources of relief. As an example, during the 2007 wildfire disaster in California, Twitter[1] was employed by local citizens and organizations to provide updates about wildfires in the region. Another example during the same emergency situation was the use of Google Maps: people created and annotated maps with markers indicating burnt areas, evacuation areas, shelters and schools. One of the most popular maps was created and maintained by KPBS news, which received more than 1.7 million views over the course of the firestorm (Sutton et al., 2008). E-mail, Instant Messaging tools and Social Networking Systems like Facebook[2] can be used to trace on-line users activities and to determine whether people are safe or not, once again by exploiting the potential of social and collaborative activities. For instance, IM can inform on the on-line status of a user telling us whether she is currently connected or not. Facebook is a website allowing users to connect and interact with other people; it was used by students during the shooting at Virginia Tech in April 2007, to provide and share critical information and activities going on at the campus, informing quickly on the casualties and injuries (Palen et al., 2009).

Geography also plays an important role in emergency management and a visual representation of geographical data makes this information tangible and useful. Therefore, interactive web maps are increasingly becoming a place where knowledge and meanings can be traced and visualized: current web mapping services like Google Maps, Google Earth and Yahoo! Maps, for example, provide features enabling users to quickly create and share customized 2D and 3D maps with relatives or friends. Furthermore, cartographic data can be annotated with geo-referenced multimedia content such as images or videos. At this stage the potential of connecting multimedia content over the web through locations metadata has become straightforward.

However, a disaster is not just an event that happens at some place and moment. It is a process that evolves and has implications in the aftermath. It is also a multidimensional process (Oliver-Smith, 2006), as stated by Liu and Palen (2009), that is physically and socially experienced by different people in different ways, so that different narratives from the same events coexist. For instance, in a wild fire, a journalist will focus on victims and damages; an emergency officer can be more interested on understanding how her organization did cope with the disaster to identify weaknesses in the emergency plan; an economist might be interested on understanding the economic effects on the area and the police might be interested in analyzing how the fire started. All of them will build, whether individually or cooperatively, different narratives of the same disaster to meet their goals.

Web Mashups

A mashup is a Web application that combines data or functionalities from different sources or services into a single integrated tool (Zang and Rosson, 2008) and implies easy and fast integration of existent services. As a matter of fact, the widespread of such applications is the direct result of the availability of open APIs offered by different Web services. In any case, mashups are more than Web sites that combine functionalities of two or more services (Wong and Hong, 2008). Mashups allow non-professional developers to build their own Web

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[1] www.twitter.com, a social network that enables subscribed users to send and read other users' updates in the form of text-based messages.

[2] www.facebook.com

application, taking advantage of the tremendous amount of content available on the web (Wong and Hong, 2007).

Web mashups are important during emergency situations as they can be created very quickly to collect and disseminate useful information. They are also relevant for citizens. In fact, it is likely that in any serious disaster, private citizens (depending on the technical skills) develop their own mashups, in order to organize among themselves and share information. There exist many examples of rapid mashups developed during crisis situations (Liu and Palen, 2009). They mainly exploit mapping services, like the one offered by Google Maps, in order to connect multimedia content over the Web through locations metadata and integrate such georeferenced content into an existing digital map. One of the clearest examples of such mashups is the Chicago Crime Data Web site[3] (formerly ChicagoCrime.org), which integrates crime data from the Chicago Police Department's database with cartographic data from Google Maps. Another simple example is the Hurricane Digital Memory Bank Web[4] site, a project to collect and share users' digital contributions on the hurricanes Katrina and Rita.

ANALYSIS OF DESIGN DIMENSIONS: TOWARD A FRAMEWORK FOR THE NEXT GENERATION MASHUPS FOR EMERGENCIES MANAGEMENT

Our findings in the analysis of 16 crisis-related mashups (see Annex I) led us to develop a general framework that can guide designers of next generations' web tools for emergency management. We revised the selected mashups by using usability inspection methods (experts' evaluation techniques without users) like cognitive walkthrough and standard inspection.

We carefully selected the mashups starting from the 13 systems surveyed in the Liu and Palen (2009) work, all of them presenting strong spatial and temporal features. Our objective has been to classify mashups according to some crisis areas we identified (e.g. hurricanes, wildfires, earthquake and so on). Therefore, we only selected from the Liu and Palen (2009) survey, systems that we considered as representative examples of each category. We excluded from our classification systems that did not provide any innovative or relevant functionality with respect to the other mashups (like the 2008 Mumbai Terrorist Attacks mashup) that seemed redundant in our proposal of survey. We then extended our analysis including all the existing literature (up to our knowledge) until now, by searching over the web for examples of mashups employed during crisis and including in our survey only the most representative systems (the ones with the most peculiar features). We focused on aspects that go beyond the spatial and temporal components. For example, aspects related to the Web 2.0 philosophy (user-generated content, collaboration, participation and so on) can be equally helpful in understanding and explaining how design choices can stimulate certain interactions and data visualization in novel crisis-related mashups.

We indentified two three-dimensional spaces depicting the design space: the first one, the *space of metadata* (Figure 1.a) refers to aspects related to specific properties of the information managed by mashups while the second one, the *space of functionalities* (Figure 1.b) describes features that a crisis-related web system ought to provide.

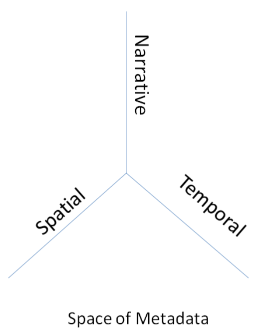

Figure 1.a: The space of metadata.

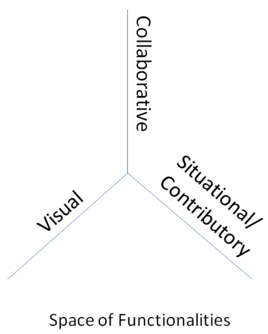

Figure 1.b: The space of functionalities.

[3] chicago.everyblock.com/crime

[4] http://hurricanearchive.org/

A survey of existing crisis-related mashups

We present, in this section, our survey of 16 crisis-related mashup systems. By analyzing features and functionalities of such web applications we aimed at identifying aspects that can be crucial in the design of next-generation mashups. We took into account the previous work of Liu and Palen (2009), but we moved a step ahead by defining a general framework that considers both information properties (such as spatial and temporal dimensions) and functionalities useful to manage contents. The results of our study are summarized in Table 1 (see Annex I).

Design dimensions for metadata

We discuss here the design implications of the three dimensions for the *space of metadata*: *Spatial*, *Temporal* and *Narrative* and the way they affect system functionalities.

Spatial and Temporal

Liu and Palen (2009) deeply analyzed the role of space and time in order to frame social interactions during crisis situations as well as the role of ICT tools in such situations. In their work they highlighted the weight that spatial and temporal features have in the description of a crisis situation, seeing emergencies as *"occurring in phases and being organized in spatial zones"*.

All the mashups we reviewed have the same problem: cluttered display screens. The system interface could result useless if the user has to browse within a vast amount of information displayed in a chaotic fashion. To avoid this problem, filtering tools that exploit the conjunction of spatial and temporal features are needed.

Timelines turn out to be powerful tools to provide the user with an interface for efficiently browsing in a collection of discrete events (André, 2007). Timeline widgets, like the one implemented within the Simile[5] project provide highly interactive functionalities and allows the visualization of events in spans of time. These widgets scale well with small amount of information but they are not able to scale effectively with large datasets (André, 2007). As a matter of fact, timelines have to be combined with filtering tools to reduce clutter of information.

Depending on the design choices and the subtending rationale, searching features can be helpful to quickly retrieve useful information. Search can be also a powerful tool, when combined with spatial and temporal components. In system like Earthquakes in the Last Week (see Table 1, row 4 and Figure 2.a), where spatio-temporal searching features are not included (i.e. specifying a date or time interval), only the visualization of multimedia information is allowed. It cannot allow users to search for a specific place or a temporal interval but allows focusing on earthquakes-sensitive world regions (Asia, Oceania, Japan, Europe, South America, Alaska and California). In order to focus on a specific place users have to move in the interactive maps and zoom in the desired area. Generally, mashups dealing with spatial data at a global scale need such search facilities. In design choices like mashups generated by the Ushahidi Engine (Table 1, row 13 and Figure 2.b) (see also War on Gaza mashup[6]), such tools can be avoided, dealing the system with a limited geographical area. In the Wildfires in California 2008 mashup (Table 1, row 9 and Figure 2.c), a temporal search box is employed to select the starting

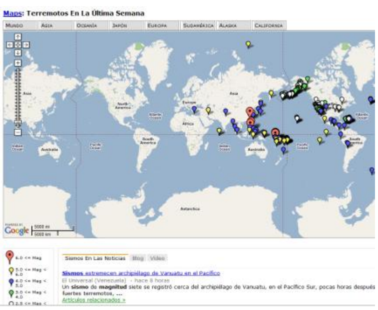

Figure 2.a. Earthquakes in the Last Week UI.

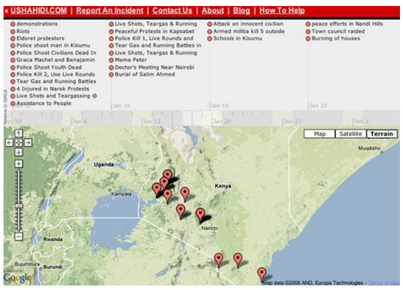

Figure 2.b. Ushahidi: UI of a mashup generated with the engine.

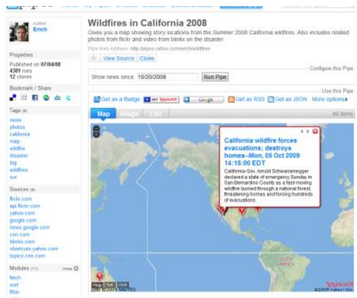

Figure 2.c. Wildfires in California 2008 UI.

[5] simile.mit.edu/timeline/docs/

[6] http://labs.aljazeera.net/warongaza/

date of the news to be showed in the map. If temporal search functionalities are not present, the timeline slider can be used to select a date (or a time period) of interest and to displace between temporal intervals.

Narrative

We believe that the participative nature of the Web 2.0 environment has to be taken into account in the design of next-generation crisis-related mashups. In collaborative tagging systems (like delicious.com or Flickr), users add metadata to community-shared material employing descriptive terms known as *tags*. This kind of non-hierarchical labels allows classifying or categorizing content for future navigation, filtering or search. The creator of a document usually chooses the tags informally and personally. The collaborative tagging process allows users to conceptualize, describe, and share resources. As an example, users can assign a set of tags simplifying the search of resources by providing indications to other users. Mashup systems can take advantage of such a process by exploiting user added metadata. Tags can be used either as a further source of information as well as a means for classifying and organizing large and messy collections of multimedia content.

Kennedy et al. (2007) analyzed how to understand and extract patterns form these collections of data. In particular they showed an approach based on location, tags and computer vision to retrieve images of geography-related landmarks and features from the Flickr dataset. They demonstrated that such "*context-annotation-content analysis has the potential to assist in various critical tasks involving media collections"*, including: *a)* improving precision and breadth of retrieval for landmark and place-based queries. *b)* soft annotation of photos, or suggesting tags to un-annotated geo-referenced photos uploaded by users, c) generating summaries of large collections by selecting representative photos for places and identified landmarks. The combination of geospatial information with tags turned out to be an important source of structure for multimedia collections (Crandall et al, 2009). Such approach can be employed in novel mashup applications either as a ranking mechanism to present only the most important content for a given query or as mechanism to visually clustering relevant information on a map.

Figure 3. Representative tags for the San Francisco area (taken from Kennedy et al., 2007).

Employing clustering algorithms on textual tags (in their work Kennedy et al. (2007) give examples of the techniques employed in the Yahoo's World Explorer[7], see Figure 3), as a way for extracting knowledge about locations, can be useful to study spatial trends and recognize geographical vulnerabilities of a certain area with respect to a particular natural disaster. In this case, the narrative nature of the tagging process can be exploited to add contextual information to spatial data and open to interesting research possibility to this design direction as also pointed out by Liu and Palen (2009).

Clustering and information categorization can be used as data filters. Filtering data on the maps, according to an assigned category, in order to reduce information clutter can result in a good design choice. For example, the Ushahidi engine allows users to assign their reports to a category, selected among a list of predefined ones (**Error! Reference source not found.**.a). Tags analysis can be helpful either to build systems for automatically select categories or guide users in the choice of predefined ones.

Design dimension for functionalities

We discuss here the proposed dimensions for the *space of functionalities*: *Collaborative*, *Situational/Contributory* and *Visual* (see Figure 1.b) along with the implications in the design rationale of crisis-related mashups. We would like to point out that in emergency mashup systems a good design choice is to

[7] http://tagmaps.research.yahoo.com/worldexplorer.php

adhere to the Maeda's Laws of Simplicity[8]: "*more features do not always result in a better system --- feature growth can make an interface too difficult, complex or unwieldy to use"*.

Collaborative

In this case we refer to collaboration with respect to the production and consumption of online content. As an explicit activity, collaboration deals with a group of users working together to generate new content, even combining existing information. Implicit collaboration, instead, takes into consideration actions of people that in the future can benefit others in browsing and accessing published content.

As discussed in the previous section, the social nature of Web 2.0 encourages applications that enhance users' collaboration. Design rationale encourages public sharing of resources so that, for example, shared tags can be used to browse, filter or track information resources of mutual interest. Social networks represent a good source of information, over a certain period of time, for events concerning crisis situations. Facebook, for instance, was used during the shooting at Virginia Tech in April 2007. Therefore, mashup designer have to consider the possibility of gathering data from them. Hurricane Ike mashup (Table 1, row 2) is an example, a map-based interface display Twitter posts about the Hurricane Ike.

Systems supporting disaster management must help users in facing information overload, providing ways to obtain available information quickly and possibly with minimum effort. Implicit users' collaboration (through collaborative filtering) can be successfully exploited to satisfy such needs.

Interesting topics concerning implicit collaboration are collaborative filtering and recommendations systems. In traditional collaborative filtering (Linden et al., 2003), recommendations from similar customers' items are selected using various methods. A common technique is to rank each item according to how many similar customers purchased it.

Situational/Contributory

There are two aspects of situational elements that constitute mashup applications: *a)* Situational designers and *b)* situational contributors. In fact, such systems are, generally, designed by situational designers to extract information for their own use from collaborative systems such as Flickr, Del.icio.us, Technorati, etc. By situational designer we mean a person developing an application for her personal use that can be shared over the web. Situational contributors are people who start to contribute to the mashup application when a specific event of interest occurs. For example, during a disaster people might want to publish pictures or information about the state of the damages. Situational or contributory dimension should be taken into account when designing mashup systems dealing with emergency situations. From our analysis resulted that, in general, systems supporting situational dimension do not provide any collaborative feature thus inhibiting strong collaboration when it comes to publishing information instead of visualizing it, like in the Ushahidi and Chicago Crime Data (Table 1, row 12) cases.

Crisis-related mashup can take advantage of users' participation in the generation of information over the web by providing tools supporting such social practice, such as reports and feeds. Sutton et al. (2008) demonstrated the efficacy of back-channels communications during emergency situations and how social media can be employed to boost crowdsourcing activities. As an example, the Ushahidi platform provides functionalities for user to generate reports about a crisis event (see Figure 4.b) that can be placed on a map. It offers a form filling interface where a user can insert all the required information. This fact clearly shows how the presence of information and communications technology is changing the disaster response arena, making back-channel communications and people involvement more tangible and useful during an emergency. In many occasions they make it possible to get an updated view of a situation or just help people to reduce their anxiety by sharing their experiences. The Ushahidi engine also allows users to submit incidents exploiting a variety of service ranging from social networks services (such as Twitter by employing special *hashtags*[9]) to short messages from mobile phones.

It is known that in a disaster situation people need information (Sutton et al., 2007). They seek it for themselves and, at the same time, try to provide helpful information to other citizens, including their relatives or friends. Design choices that allow users to send alerts to a list of subscribers can help people to stay in touch and quickly

[8] http://lawsofsimplicity.com/?p=50

[9] Hashtags are a convention for adding additional context and metadata to short message in Twitter community. They appear like labels added inline to your post and prefixed with the symbol #.

inform on the development of the events (Malizia et al., 2009b). Current systems, like Ushahidi, only allow sending reports that can be visualized by the application. Novel mashups should provide features similar to the ones provided by social networks: for example manage a list of other users with whom a user is connected to as well as the possibility to visualize alerts and news sent by each contact. Users should also be able to select the way they prefer to receive the alerts: via RSS feed, SMS on their mobile phone or updates on their contact list.

Instead of subscribing to receive certain user updates, it could be interest to investigate the potentials in combining spatial and temporal dimensions so to enable *contextual alerts*. As an example a user could subscribe to receive alerts and reports affecting certain geographical area in a chosen time span.

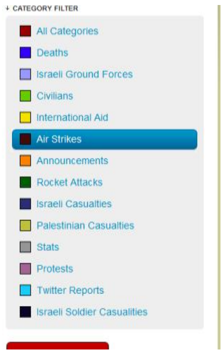

Figure 4.a. List of categories of the Ushahidi engine.

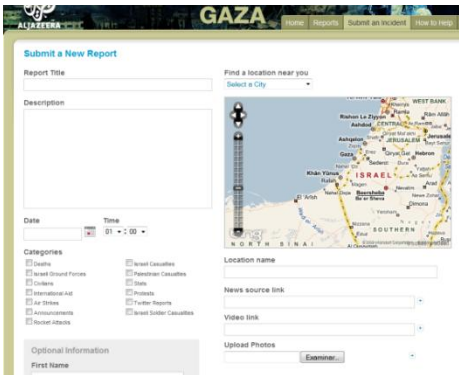

Figure 4.b. Ushahidi: form filling interface for generating a report.

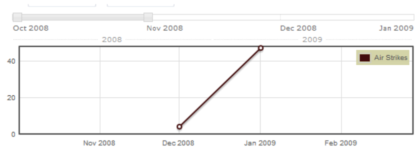

Figure 4.c. Ushahidi: overview of reported incidents over time.

Visual

Systems supporting disaster management must help users in facing information overload, so proper visualization technique must be implemented in order to display useful information as efficiently as possible to the users. Many aspects of design choices related with content visualization can be discussed.

Revised systems employ different techniques in order to express spatial features (like the concentration of information in the same place) or temporal ones (the freshness of the information). As reported by Liu and Palen (2009), for example, in the Live Earthquakes mashup (Table 1, row 5) the temporal component, associated with the information, affects the way icons are displayed in a map: *"The icon size is based on the magnitude but the icon becomes more transparent as it gets older"*. Mashups created with the Ushahidi engine, instead, exemplify how the spatial component of data affects icons visualization: they employed a design choice for which icon size is determined by the number of reports in the same spatial region.

Another aspect of information visualization is related to the color-coding for the icons on the map. Each one of the revised systems presents a different design choice with respect to the color of its icons. In Earthquakes in the Last Week mashup, icon colors refer to earthquake magnitude in the Richter scale. The Global Flood mashup (Table 1, row 5) employs a color code of different tonality of green, from dark green to blue, to display the current elevation of a place and its elevation after sea rising. In this way users have a quick overview of these sites where an excessive rise of the sea level can affect more. Ushahidi use color codes for the report displayed on the map that depend on each report category.

Finally, it can be interesting to visualize statistical data. Emergency-related mashups can be created and used by both citizens as well as member of governmental agencies and practitioners: these latter can be interested in studying, for example, the activity of users over time or trend of reports submitted in a chosen period of time (Ushahidi provide a widget on its interface to visualize an Overview of reported incidents over time, see Figure 4c).

ESTORYS

eStoryS (emergency Storyboard System) is our web mashup system for helping people and professionals to retrieve, create and share information about emergencies and disasters presenting strong *narrative* features (Malizia et al., 2009a). It provides a combination of tools that turned out to be effective during crisis situations such as: spatial-temporal search features, recommendation and filtering tools, and storyboards. The system was developed as an instance of the proposed framework.

This web application employs the Flickr API to retrieve pictures from its database (*narrative dimension*) and make use of location metadata to accurately place such images on a map, exploiting the Google Maps API (*spatial dimension*). Users can search for a geographic area entering any combination of address, city, state or zip code. Subsequently, the system retrieves all the georeferenced photos taken within the selected area. Finally, the retrieved pictures are placed on the map according to their location (*spatial dimension*).

Pictures are retrieved also considering the *temporal dimension*, in conjunction with the spatial one. The system interface enables users to select temporal intervals and subsequently retrieve such photos with a shot date within the given range. For example, the *temporal dimension* can be exploited to enable time-based retrieval over *spatial* locations. eStoryS provides both *spatial* and *temporal* searching features enabling spatio-temporal queries: a text box allows users to specify a geographical location of interest and a calendar widget allows to specify a date. Moreover, the system implements three basic components in order to specify constraints on the temporal properties: *a)* a calendar, *b)* a temporal window box and *c)* a timeline slider. These components allow users to express their query by time (see Figure 5).

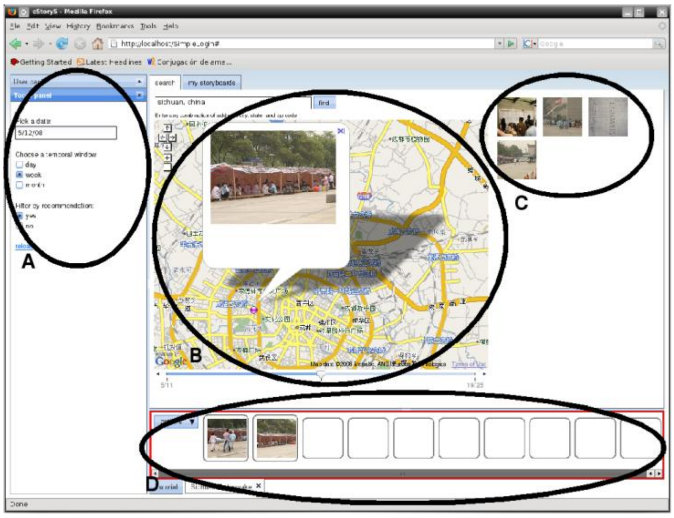

Figure 5. The UI of eStoryS. A) temporal and filter settings; B) digital map panel; C) ranked list of retrieved images; D) storyboard authoring panel.

Regarding *collaborative* functionalities eStoryS implements a simplified version of the algorithm in which the ranking of retrieved images is computed according to how many different users have double-clicked on each image. As a matter of fact, eStoryS supports social navigation in the sense that users' past interactions with the system are employed as recommendations, impacting on the way the information is presented during other users' interactions. We can assume here that during, or immediately after, an emergency the most viewed images for a given area are probably the most relevant ones, with respect to the specific emergency (e.g. photos of damaged buildings, firefighters rescuing people, etc.).

The Storyboard Authoring mode allows the creation of spatio-temporal slideshows of selected images (*situational/contributory dimension*). To our knowledge, eStoryS represents a first attempt to integrate *collaborative* and *situational*/*contributory* features in a single tool. It exploits implicit user collaboration as an information filter and allows building collaborative storyboard of images. Systems adhering to the *situational/contributory* design dimension generally promote crowdsourcing, defined as a distributed problem-solving and production model where the *crowd* (users organized in online communities) submits solutions to a proposed problem. It leverages the efforts of many people to accomplish a more complex and worthwhile task.

By comparison with all the revised mashups, eStoryS is the only one implementing storyboarding features (*narrative dimension*). From the *narrative* point of view, storyboarding features can be a relevant functionality to provide to users during an emergency. Storyboards are visual organizers, such as series of illustrations or images displayed in a sequence. The use of storyboards to present and describe interactive events it helps situational contributors (people publishing multimedia content during a specific event or for a specific purpose like an emergency) to group data and publish sequences of events on the system. In such a case, a storyboard can be considered as a way for the user to create her script of a particular event, improving the collaborative processes of creating shared awareness and understanding out of different individuals' perspectives and interests. In eStoryS we provided storyboarding features for quickly generating slideshows by exploiting drag-and-drop of selected images. In order to create a storyboard, a user can select pictures from a list of images (retrieved by the system) and drag such images directly into the storyboard panel.

The Storyboard building process turns out to be helpful in situations of high complexity or uncertainty, in order to make decisions. It helps in enhancing sensemaking activities (Landgren and Nulden, 2007) of constructing a hypothetical mental model of the current situation, how it might evolve over time, what potential actions can be taken in response and what values drive the choice of future action. Storyboarding can also be useful for the preservation of spatial and temporal information flows. As Liu and Palen (2009) stated, *"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"* and *"easy accessibility to historic data not only can help us learn from past practices but also inform us of geographical vulnerabilities"*.

Usability of proposed system has been evaluated employed three different evaluation techniques: *(i)* analytic, *(ii)* heuristic and, *(iii)* experimental (Malizia et al., 2009a). Concerning *(i)* the analytic evaluation, we designed two scenarios for comparing our system with two other mashups exposing similar features. In *(ii)* the heuristic evaluation, experts (12 participants selected among a group of students (master courses on hypermedia and HCI) of the Computer Science Department at Universidad Carlos III de Madrid, Spain) were asked to examine the interface design to determine its compliance with a short list of usability principles.
Finally, we conducted *(iii)* an experimental evaluation with 34 participants. The participants were asked to perform three tasks of incremental difficulty and to fill a post-task questionnaire. The objective of the task was to simulate the use of the system in scenarios that are likely to be the most appropriate for its use.

CONCLUSION AND FUTURE WORK

In this paper we presented a survey of 16 map-based mashups (see Annex I). The analysis of such systems led us to develop a high-level framework that can guide in the design of next generations Web tools for emergency management. In particular we highlighted two design spaces: *a)* the *space of data* and, *b)* the *space of functionalities*. The first one concerns with that aspects related to the information managed by mashups while the second one takes into account different functionalities of crisis-related mashups. We also presented our system, eStoryS (Malizia et al., 2009a), developed as an instance of the proposed framework.

Designers (professional as well as occasional) have to consider how data and functionalities can be combined so to create mashup applications that can be useful for a wide range of users and for different crisis situation.

As a future work,we believe that our general framework can be considered as a first effort toward the development of a visual language for Web based Emergency Management Information Systems (WEMIS). In fact, following the rationale of our framework, it could be possible to define visual elements corresponding to desired functionalities. In this way end-users, with no programming skills, can quickly develop their crisis-related mashup, exploiting the visual elements for combining different web services and content.

ACKNOWLEDGMENTS

This work is funded by the grant UrThey (Ministry of Science and Innovation TIN2009-09687)

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ANNEX I

Crisis Area	Mashup Name	Mashup URL	Technologies and Data	Brief Description	Comments
Hurricane	Tropical Storm Update	http://pipes.yahoo.com/erich/storm	Yahoo Maps, Yahoo Search, Yahoo Pipes	Get news about specific tropical storms and hurricanes	No temporal information about news is provided.
	Hurricane Ike	http://www.mibazaar.com/hurricanes.html	Twitter, Twittervision, YouTube, Google Maps	See in realtime the Twitter chatter about Hurricane Ike and the videos posted on YouTube	Although this mashup design does not provide collaborative features it is interesting in the way we show how user-generated content coming from a social system (like Twitter) can be exploited to gather useful and up-to-date information about a disaster
	Hurricane Tracker	http://samuel.foucher.googlepages.com/Hurricane.html	Google Maps, National Hurricane Center forecasts	Track the latest hurricane on a Google Map: forecasts, observed tracks, refinery and oil rig positions.	Special icons are employed to visualize next and previous forecast taken from the National Hurricane Center
Earthquakes	Earthquakes in the last week	http://earthquakes.tafoni.net	USGS data, Google Maps	These two map-based mashups show earthquakes that have happened around the world in the past 7 days.	Share the same rationale: they exploit data from different sources to display earthquakes activities all over the world in the last seven days.
	Live Earthquakes	http://www.oe-files.de/gmaps/eqmashup.html	Google Maps, USGS, EMSC and GFZ data,Simile Timeline		Live Earthquake Mashup presents interesting features: it employs a timeline slider widget, by which a user may shift between temporal intervals by moving an indicator.
	Seismo-surfer	http://www.seismo.gr/	Google Maps, USGS data	A WebGIS application for integrating, visualizing and analyzing seismic data.	GIS functionalities such as panel for controlling the layers and their properties, dialogs for displaying feature attributes and tools for setting projections, saving and printing map
Wildfires	LA Times Wildfires Map	http://www.latimes.com/business/la-me-la-fire-photo-map-	Google Maps, Los Angeles Times	Detailed information on the October 2007 wildfires in southern California.	Markers have details such as acres burned, current containment, homes destroyed, time started, and status of evacuations.
	KBPS Sandiego Fires	http://maps.google.com/maps/ms?msa=0&msid=114250687465160386813.00043d08ac31fe3357571	Google Maps, County Emergency Operations Center data	Map with latest news about the October 2007 wildfires in southern California.	Includes fire areas and meeting points for evacuees, as well as nearby emergency services such as hospitals.
	Wildfires in California	http://pipes.yahoo.com/pipes/pipe.info?_id=RIuSHE6C3BGakzE3JphxuA	Flickr, Yahoo Maps, Yahoo Pipes	Presents wildfire news stories, using a map.	Uses Yahoo Pipes to offer RSS feeds from southern California newspapers, Flickr, and MSN video of the disaster.

Crisis Area	Mashup Name	Mashup URL	Technologies and Data Sources	Brief Description	Comments
Floods	Global Flood Map	http://globalfloodmap.org/	Google Maps, Flash, NASA satellite data	Interactive map that allows what areas would be flooded or at risk due to sea level rises that may be related to Global Warming.	Users can enter their own estimate and see which cities are flooded
	Flood maps	http://flood.firetree.net/	Google Maps, NASA satellite data	Interesting combination of Google Maps with elevation data to show the impact of rising sea levels.	
Crimes	Chicago Crime Data	http://chicago.everyblock.com/crime/	CLEARMaps, Chicago Police Department crimes data	Mashup that allows users to explore reported crime in the city of Chicago in various ways	The information reflects incidents where the police responded and completed case reports.
Crisis situations	Ushahidi	http://www.ushahidi.org	Google Maps, Users-generated reports	It aims at gathering user-generated crisis information, allowing anyone to submit content through text messaging using a mobile phone, email or web form	Users can submit their reports about an event, assigning them a name, a brief description, a date, a category (within predefined ones) and a location.
	Sahana	http://www.sahana.lk	Google Maps, Users-generated reports	It is a web based collaboration tool that addresses the common coordination problems during a	
	LocalAlerts	http://www.localerts.com	Google Maps, Alerts from different sources	It publishes alerts that are specific to every local area in the United States, including Alaska and Hawaii.	Alerts from local, state and federal government, world organizations and local communities are combined and filtered to provide alerts that affect your location in areas such as weather, safety, health, internet, traffic and news.

Table 1. Survey of crisis-related mashups.