Title
Community-Based Mapping for Disaster Mitigation and Response

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Abstract
Many disaster mitigation and response projects throughout the world would benefit greatly from recent geospatial information and timely collection of data. In particular, vulnerable areas of the developing world have the greatest to gain--but these areas usually have minimal resources available. Skilled mapping teams and capable hardware are unlikely to be located in these areas when disaster strikes and prior information is often difficult to access. This presentation describes a community-based mapping system that can be used for disaster mitigation and response by members of the local community. In a preliminary trial of this system in a poor, flood-prone area of El Salvador, each of two teams of local staff used a handheld computer running ArcPad to conduct a digital questionnaire in residents' homes after less than ten minutes of training. The information was collected during the day and was synchronized and published at night.

Paper Body

Introduction

Geographical Information System (GIS) technology is reaching a broader audience thanks to many factors, including inexpensive computing power, Internet connectivity, and user-friendly software. GIS proponents would like to see the benefits of the technology become available throughout the globe – not only to First World corporations but to Third World citizens as well.

One particular area where GIS technology can be brought to bear on a global scale is in disaster response and humanitarian relief. Natural and man-made disasters are occurring at an increasing pace, causing significant problems for billions of people. Natural events such as earthquakes, floods, and hurricanes can be completely catastrophic for the societies they affect. Man-made disasters not only result as a consequence of human actions, but also of inaction when community vulnerability is increased due to poor anticipation and mitigation of these events. Catastrophes are not “equal opportunity” events – Third World countries have less robust construction, denser populations in vulnerable areas, and limited resources for response. Throughout the humanitarian aid community, a great deal of effort is dedicated to response and mitigation planning in order to diminish the impact of all types of disasters.

Many of these disaster mitigation and response projects would benefit greatly from timely geospatial information. The collection of geospatial information about communities, their families and the environment can assist greatly in planning for community development and disaster mitigation. Early warning systems, assessment of roads and housing, the provision of adequate water and food supplies, monitoring and improvement of health care delivery, and the spread of advanced farming techniques can all be enhanced through better geospatial information about communities in need.

Relief organizations, too, can benefit from access to more comprehensive geospatial information about the communities they serve:

- Strategic infrastructure planning can be more comprehensive and can utilize advanced geospatial analysis tools to improve positioning and purchasing
- The productivity of personnel throughout the organization can be increased by providing better information to them
- Higher quality data presentation is available for proposals and reports than those created manually, at lower cost
- Facilitated decision making and improved coordination within and among agencies
- Digital recordkeeping of the state of the communities for historical analysis of program effectiveness.

Ultimately, vulnerable areas of the developing world have the most to gain from this information – yet these areas usually have minimal resources available to create it. Skilled mapping teams and capable hardware are unlikely to be located in these areas when disaster strikes and prior information is often difficult to access. The time spent getting mapping teams to the site adds to the cycle time for aid delivery. New creative approaches must be tried. LumiMap, a non-profit founded to provide geospatial technology and expertise to humanitarian relief organizations, has developed a community-based mapping method that will be discussed in this paper.

Approach

Though a variety of people can clearly benefit from geospatial data, collecting it in Third World environments is challenging: little technology infrastructure is in place, the personnel who are available are likely not technical, and the work is often in remote locations. LumiMap has proposed the broad deployment of community-based mapping to address many of these problems. Community-based mapping, for the purposes of this paper, means providing members of a local community with the means to create, populate, and/or distribute maps of their community. This community-based mapping concept is the result of an ongoing search for an effective system of geospatial data collection in the Third World: let locals assess their community using a simple in situ system, then use

the Internet to enable access to centralized technology expertise and to distribute the results globally.

One significant benefit of community-based mapping is that it directly builds capacity in the targeted community. Not only is the new infrastructure useful for disaster assessment and response, but also for disaster mitigation and for non-disaster community assessment. By using digital communication technology, particularly the Internet, the community-based approach can achieve a significant percentage of the capability of a specialized mapping program conducted by experts.

Community-based mapping requires only minimal personnel and infrastructure on site and utilizes non-expert assessors. The primary LumiMap design criterion was to present to the user community a simple system: simple data entry interface, simple synchronization process, and simple information access. LumiMap goals to install a mapping program in a community are one half-day of training for the main local supervisor and 15 minutes of group training by the supervisor to individual assessors. This is accomplished by a user-centered design process for the handheld computer user interface and a strict limitation on the types of data to be collected.

The result is a technology capability that provides sustained, low-cost preparedness for assessing and responding to disasters. Between uses, the system can be left primed and ready to go: assessment forms are stored on the handhelds kept charged in local closets, blank maps are kept ready for data on the web server, and hyperlinks can be set as bookmarks and onto aid organization websites.

Implementation

The LumiMap Global Mapping System (GMS) is comprised of three primary technologies that can be utilized independently or, most effectively, as a group of diverse components to provide a flexible, deployable mapping infrastructure. These three components are a handheld data collection system, a web-based geospatial data distribution system, and small inexpensive unmanned aerial vehicles. For community-based mapping, only the handheld and web-based systems are used.

Handheld collection system

LumiMap utilizes ArcPad, a GIS software package produced by ESRI, for handheld data collection. ArcPad was created to provide geospatial data entry and retrieval for handheld and laptop computers working in a field setting. ArcPad is not capable of advanced GIS processing or data management; these tasks are carried out by more powerful GIS packages such as ArcView, ArcEditor, and ArcInfo (also ESRI products). The handheld hardware used in the LumiMap GMS is a Windows CE / PocketPC device, typically a HP/Compaq iPaq

with a GPS module but sometimes a more ruggedized device such as a Trimble GeoXT. The choice of hardware depends on the project environment and the project budget, as the ruggedized hardware can be significantly more expensive.

The GIS hardware and software, which are mostly used "out of the box" without major modification, are the foundation for the handheld collection system. LumiMap then adds in-house expertise in the design and development of digital surveys and assessments and in the synchronization of field data. When the LumiMap GMS is deployed, LumiMap personnel work with aid agency staff to develop appropriate digital surveys in each area of interest for both time-critical rapid assessments for disaster response and more intentional assessments for disaster mitigation or community information. LumiMap also equips and instructs the aid agency in the data synchronization process.

LumiMap has developed a set of design principles that are used for all survey creation. The most preferable questions are Yes/No, followed by multiple choice and numerical entry. Text entry is allowed only as a final "Additional Notes" field, though pains are taken to prevent any need for notes. These design rules result in higher quality output for subsequent data mining and automated processing. Neither handheld computers nor local assessors are suited for expository writing as a critical part of an assessment. Handheld systems are for quick collection of critical data or inexpensive collection of general data. Fortunately, these two data collection goals intersect in their basic structure – short answers rather than long text explanations.

Web-Based Distribution

LumiMap maintains a web server with persistent (24 hours a day, seven days a week) service to the Internet via a T1-connection hosted by CGNet (http://www.cgnet.com) of Menlo Park, California. This server utilizes ArcIMS web-based mapping service software created by ESRI to serve geospatial information to any web browser such as Internet Explorer or Netscape Navigator. For most deployments of the LumiMap GMS, which require database management of geospatial information and metadata and restricted access, LumiMap also uses Microsoft SQL Server and ESRI ArcSDE Spatial Database Engine. This combination of hardware and software allows LumiMap clients to synchronize their field data with the server and then instantaneously provide maps using this data to anyone in the world that has an Internet connection.

The local personnel may also distribute on-site printed maps of the collected data using ESRI ArcReader, a free GIS program that was designed to be simple to use. In this way, local action may be taken based on recently-acquired information without requiring an Internet connection, synchronization, and download from the LumiMap server. However, when Internet connections are available, local personnel may access the LumiMap server to view the same full extent of information that is available to other users around the globe.

LumiMap has expertise in designing web-based map viewing tools for non-technical use. LumiMap also provides basic training for web map use to aid agency personnel so that they may access the information directly from their offices. Access to the appropriate areas of the LumiMap web server, including access to the information collected in the field, are password-protected to prevent unauthorized viewing or use.

As with the handheld survey design, simplicity is the goal for LumiMap web-based maps for information distribution. As many of the consumers of the information have minimal GIS knowledge, the LumiMap online maps do not require data layer selection but rather generate individual maps for each important survey variable. Links are provided to download the entire dataset for use by GIS experts. LumiMap is also able to embed the maps in an agency website so that hyperlinks can be incorporated into reports while maintaining the agency look and feel.

Testing

The Republic of El Salvador has an area of 21,000 km^2 (approximately 8,108 mi^2). With a population estimated to be more than 6.3 million people, at 324 inhabitants per square kilometer it is one of the most densely populated countries not only of Latin America but of the whole world. According to the United Nations Development Program, 43% of the total Salvadoran population lives in poverty. 53% of these people live in the rural area, and 62% of these rural citizens are in absolute poverty. El Salvador's fragile economy depends much on the remittances sent by Salvadorans abroad. In addition, El Salvador is permanently exposed to earthquakes, floods, droughts, landslides, volcanic activities, and many other potential natural disasters.

Following Hurricane Mitch in 1998 and the devastating earthquakes in early 2001, a few major cities, such as San Salvador, were mapped in detail for future disasters. In rural areas, however, the maps that exist are very general and not detailed enough to provide useful data for local development and mitigation planning. As 42% of the population lives in these rural areas, it is imperative that the local communities and the agencies serving them be given the tools to conduct ongoing information collection, monitoring and mapping.

A private aid organization supported a small-scale deployment of this system in a poor, flood-prone area of El Salvador. Each of two teams of local staff and government representatives used ArcPad on a handheld computer to conduct a digital questionnaire in residents' homes which was then presented online using ArcIMS.

The objective of the survey was to obtain an overview of the housing and health status of the families and to provide the agency with community information that will be valuable for mitigation planning before, during and after the next flood or

other natural disaster. Both villages chosen were in a high risk area for earthquakes, hurricanes and annual flooding so the information collected could be used in current mitigation planning.

Figure 1. Fisherman responds to digital survey

In the project focus area, the construction of most of the homes was either un-reinforced masonry or thatched huts with wood supports. All homes had dirt floors, no window coverings, outhouses and no running water. Half of the houses surveyed had no electricity and limited telephone access. Cooking facilities consisted of concrete grills or adobe ovens. Most families had livestock consisting of pigs and chickens which shared living space with the family. The unstable nature of the dwelling construction made the shelter for both the families and their livestock vulnerable to damage or destruction in the event of an earthquake, a flood or in high wind conditions.

Collection

In the one-day survey, 20 families were interviewed by 2 teams with 5 people on each team (see Figure 1). The survey utilized a questionnaire containing 18 questions that was created the afternoon before the fieldwork (see Figure 2 for screenshots of two of the eighteen forms used). LumiMap provided two Compaq iPaq handheld PDAs with GPS receivers for geopositioning and data collection. After arriving in the field, the teams were trained on the use of the iPAQ for approximately 10 minutes. During the course of the survey, all team members took turns conducting the surveys on the iPaqs.

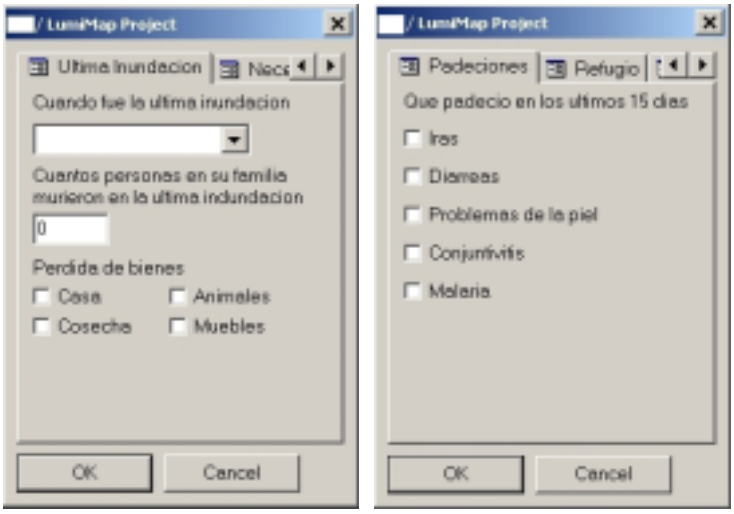

Figure 2. Example ArcPad survey forms

Each team surveyed 10 families: five in the village of Las Brisas del Mar and five in Garita Palmera Valle de Arriva. Time taken was about one hour in each location. Average time necessary to conduct the survey was seven minutes. For future deployments, the number of questions could be increased to extend the interview time to fifteen minutes or so.

For this project, a LumiMap technical advisor was available during the conduct of the survey in case any significant problems arose. The need for onsite technical support was minimal and for future short-term deployments only centralized support from LumiMap in the United States should be required. For long term extensive surveying of a country, one centrally located LumiMap technical support advisor available in-country to support multiple field teams should suffice.

Synchronization was carried out by LumiMap technical personnel on-site via existing direct Internet connection. Local staff was given a general overview of the synchronization process. Future synchronization can be carried out either by direct Internet connection or dialup via satellite phone.

Distribution

LumiMap created individual web-based maps for each important variable so that static hyperlinks could be emailed and bookmarked, and so that personnel new to GIS would be able to understand the information without risk of confusion. The single-variable mapping technique allows direct referencing in reports and email, easy comparison between maps using multiple browser windows, and collaboration between personnel without GIS system knowledge. Comparisons between variables and other basic analysis needs were not required by the aid agency, but LumiMap does provide a link at the bottom of each webpage to download the entire dataset for those users who have GIS software expertise.

No example maps are shown to protect the anonymity of the sponsoring organization.

Conclusion

The community-based mapping project completed in El Salvador demonstrated the feasibility of local deployment of the LumiMap system in remote areas. Overall, the use of the PDAs greatly expedited the speed of both the collection of information and the subsequent data collation and map creation. The survey creation, assessment, and distribution process normally takes the sponsoring agency one month or more to complete. This deployment was completed in just over 24 hours and the results were of a higher quality than the agency standard due to the addition of the map component. The survey design, with the use of drop down menus and multiple choices, was designed for simplicity and efficiency and it served its purpose well. Internet distribution of the data enabled organization-wide use of the data almost immediately after it was collected.

Community-based mapping promises to be a success for certain types of assessments – it requires minimal training and small local infrastructure and provides distributed assessment and data collection, while the technical expertise and main infrastructure can be centralized and costs shared. The data can be redistributed to a global audience, ultimately cross-pollinating the communities that had no access to geospatial data before with new information and new assessment approaches.

The handheld computer and web-based community-based mapping service provided via LumiMap should, among other things, enable more accurate targeting of aid and resources, earlier notification of impending food security needs, more detailed planning capabilities for rehabilitation and disaster mitigation activities, and enable aid organizations to more closely evaluate and provide for the needs of local communities.

Acknowledgments

LumiMap would like to thank ESRI and ESRI staff for their generous software grant program for humanitarian-related efforts[1] and their helpful advice, particularly Carmelle Cote, David Gadsden, Charles Convis, and Chris Grasteit. LumiMap would also like to thank CGNet[2] for their in-kind contributions for web serving and Internet connectivity.

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