Mobile Geotagged Data Gathering for Disaster Remediation

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***Abstract*—Devastating floods in Thailand during the final quarter of 2011 caused almost 600 deaths as well as severe damage to the country's infrastructure and economy. The crisis prompted us to very quickly develop a system using mobile devices to survey the status of industrial facilities in disaster-affected areas. Our objective was to create a system that would allow an untrained user equipped with a modern mobile telephone to acquire and transmit location-tagged information, in multiple modalities, about the conditions at a disaster site. The system needed to be robust in the face of abnormal conditions in the disaster area, should permit the users to use their own language, and should make the resulting data available immediately both to supervisors coordinating the disaster remediation effort and to experts elsewhere. In this paper we describe the motivation and methodology for this project, the functional architecture of the resulting software, its present status and its future prospects. The project serves a case study for rapid application development of geospatial software. The resulting application has potential utility in other disaster situations.**

I. Background and problem statement

In September 2011, abnormally heavy rainfall in the north and northeast of Thailand produced record-breaking floods. Twenty six of the 77 provinces in the country were inundated at depths from 20 cm to more than two meters. Because of the low relief in central Thailand as well as anthropogenic barriers to natural drainage, flood waters drained extremely slowly. Many areas were flooded for two to three months.

Nearly 600 people lost their lives in the floods, mostly through drowning or electrocution, and more than 13 million people were affected [9]. According to the World Bank [11], the total economic loss as of December 1, 2011 was US$ 45.7 billion. Although the economic impact on agriculture, tourism, and private property was severe, the biggest damages and losses (approximately US$ 32 billion) were in the manufacturing sector. Central Thailand is a hub of manufacturing for both export and domestic consumption. Industrial estates located within a 150 kilometer radius of Bangkok produce everything from soft drinks to hard disk drives. At the height of the crisis, nearly all of these manufacturing estates were under water. The flooding disrupted critical links in worldwide supply chains, with repercussions as far away as the United States and Japan.

As the waters receded, many companies considered whether they should abandon their existing facilities rather than restoring them. In an effort to reassure international investors that supporting the industrial sector was a top priority, the Thai government instructed the top technical universities in Thailand (including ours) to volunteer student effort for the rehabilitation effort. At the same time, students were also expected to maintain their usual studies. This required faculty members to organize the remediation work so that it could have an educational component.

We realized that we could create a system which could provide valuable information to guide disaster remediation. Once the initial version was available, students in the field could use it to survey and document damage or hazards in the factories. Meanwhile, since we work in a department of computer engineering, other students could adapt and enhance the application, based on user feedback, to gain experience producing software for mobile devices.

This paper describes this project, which we call "CrocScope". (The name derives from the fact that during the floods, many crocodiles escaped from breeding farms to roam the countryside.)

The primary objective of the CrocScope project is to create a system which allows an untrained user equipped with a modern mobile telephone to acquire and transmit georeferenced data in multiple modalities about the conditions at a disaster site. These data are integrated on a server, where they can queried, reviewed and displayed on a map or satellite image background. The system must be robust in the face of abnormal conditions in the disaster area, must permit the users to use their own language, and must make the resulting data available immediately both to supervisors coordinating the response effort and to experts elsewhere.

II. Related work

As mobile devices have increased in power and decreased in cost, and wireless connectivity has expanded, researchers involved with geospatial applications have reacted with predictable enthusiasm. Today's smartphones are sophisticated sensor platforms typically incorporating a GPS receiver, accelerometer and compass as well as still, video and audio recording capabilities [7]. As a result, many groups have developed mobile-device-based software for geospatial applications, including field survey [3], [12], [10], disaster response and recovery [1], [2], [4], [6], and geolocated brokering of services [5]. In the domain of disaster management, research has focused on optimizing routing so rescue personnel can respond efficiently [2], providing a map-based repository for the public to search for disaster information [4], providing disaster warnings on mobile devices [6], and transmitting situation status reports to a central repository [1], [6]. The last focus most closely matches our objectives.

Current research on geospatial applications for mobile devices tends to have several common themes:

- Researchers tend to describe their work as creating a scaled down "mobile GIS". The tasks they envision performing on the mobile platform approach a desktop GIS in both data volume and workflow complexity.
- Many mobile geospatial tools focus on visualization or mapping of the phenomena of interest, often integrating third-party web- or cloud-based mapping services such as Google Maps or Yahoo Maps.
- "Volunteered Geographic Information" or VGI [5] has generated considerable excitement. VGI relates to the "crowdsourcing" of geographic data gathering, where members of the general public contribute knowledge about their current or habitual locations. VGI is particularly relevant to disasters [13], when normal transportation and communication channels may be disrupted and it is extremely difficult for decision makers and managers to gain an overview of the situation on the ground.

The CrocScope project runs counter to all three of these themes. Our goal was to create an application that would be simple for students to learn and which would provide the specific information the managers of the remediation effort need, namely the location and severity of damage and hazards. We do not view CrocScope as a GIS in any sense of the word, despite the fact that it deals with geographic data.

Compared to many studies in the literature, the goals of the CrocScope project were modest. On the other hand, the application was urgently needed, so the time available for development was very short. Furthermore, we had a real-world disaster scenario to deal with. CrocScope addresses the utility of mobile geospatial computing from a practical rather than a theoretical perspective.

III. Methodology

This project faced serious time pressure. We needed to have a functioning software system within a few weeks. This constraint forced us to adopt a Rapid Application Development methodology, rather than undertaking a deliberate and disciplined design process. First, we created a very rough functional specification for the system. Because we had no prior knowledge about the actual working conditions or activities that the users would face, we had to extrapolate from known scenarios.

A. User categories and functions

Based on discussion with other faculty and a review of the literature, we identified three categories of user:

- A person located at the remediation site, who encounters some information which needs to be reported. We refer to this kind of user as a "field worker", or as someone "in the field". The field worker is limited to reporting information.
- An individual managing the field workers, who might be located in the field or working at a desk at some distance from the remediation site. This person needs to see the accumulated information, both in summary form (including geographical displays), and in detailed form. We refer to this kind of user as a "supervisor".
- An administrative person, who would be working on a PC. This person handles creating accounts, adding work sites, etc. We refer to this kind of user as an "administrator".

B. Hardware requirements

Each category of user needs a different sort of computing device. We decided to use Android devices for mobile components because of the multiplicity of devices available, the lack of restrictions on distributing Android applications, and the ease with which Android applications can be internationalized.

The three platforms that we identified were as follows:

- A mobile telephone with software suitable for the field workers. We wanted the field worker to be able provide data in any or all data modalities that could reasonably be accommodated on a cell phone, including geotags, photos, voice recording, typed comments and structured form data.
  Given the limited development time available, we decided to standardize on a single device, an Android Samsung Galaxy II phone. This unit has the advantage of a relatively large screen size (making typing easy) and memory (making data storage for later upload possible), plus being equipped with all the needed peripheral hardware devices. Other phone models could be used if the field workers happened to have them and if the software functioned correctly on those models[1].
- A large screen tablet device for supervisors. As with the phone, we chose a specific model to accelerate development, namely, the Samsung Galaxy ten-inch tablet [2]. However, since the supervisor functionality has been implemented as a web application (to allow supervisors to work from a desktop PC as well as in the field), any Android tablet (or, actually, any tablet with a Firefox or Opera browser) should work equally well.
- Finally, we needed a server which could receive, organize, catalog, and analyze the data sets provided from the field. Although there are a variety of free cloud services available which could be used to provide the data repository, we felt that the speed of these systems would not be

[1]Software is somewhat portable across different Android devices, but that portability cannot be assumed without testing.

[2]This decision was made before sales of this device were banned in Germany.

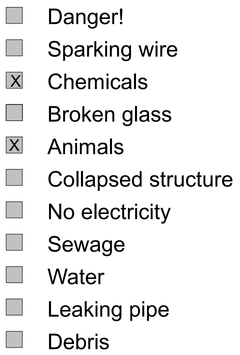


Fig. 1. Check list of hazards.

adequate for our purposes. Instead, we used a Linux-based server located in our department, and employed HTTP/HTTPS protocols for all communication between the mobile devices and the server.

C. Development plan

It was clear that the field workers would need their devices first, but also that the devices would be useless without a server to receive the uploaded data sets. Support for the supervisor could be delayed, but as soon as a significant amount of data became available on the server, the supervisor would need at least some access to it.

Because administrator tasks can always be accomplished manually, we chose to defer implementation of administrator interface until after the system had proved its usefulness.

D. Data model

Within the server, each data set, known as a ”shot”, potentially includes the following:

- A textual name for the shot
- A geotag with geographic location, bearing and time
- At most one photograph
- At most one sound recording
- At most one text file of free-form commentary
- At most one overlay file holding graphical annotations for the photograph (implementation deferred)
- A list of observed hazards (see Figure 1)
- Metadata including phone id, site, group, and field worker names, and time of uploading

The shot metadata, name, location information and hazards list are stored in a relational database on the server. The photograph, sound recording, free-form text and graphical annotation are stored in individual files which are identified by the corresponding database record.

All relevant parts of the above data are also kept in the phone, so that the field workers can review their work. The information for a particular shot is stored in local phone memory and can be changed until it has been successfully uploaded. After upload, it can only be deleted.

The name of the shot, the geotag, the other metadata, and the hazards form the basis for the search and analysis capabilities available to the supervisor. Once desired shots have been identified by a query, the information stored in files can be reviewed or displayed.

E. The field worker’s view

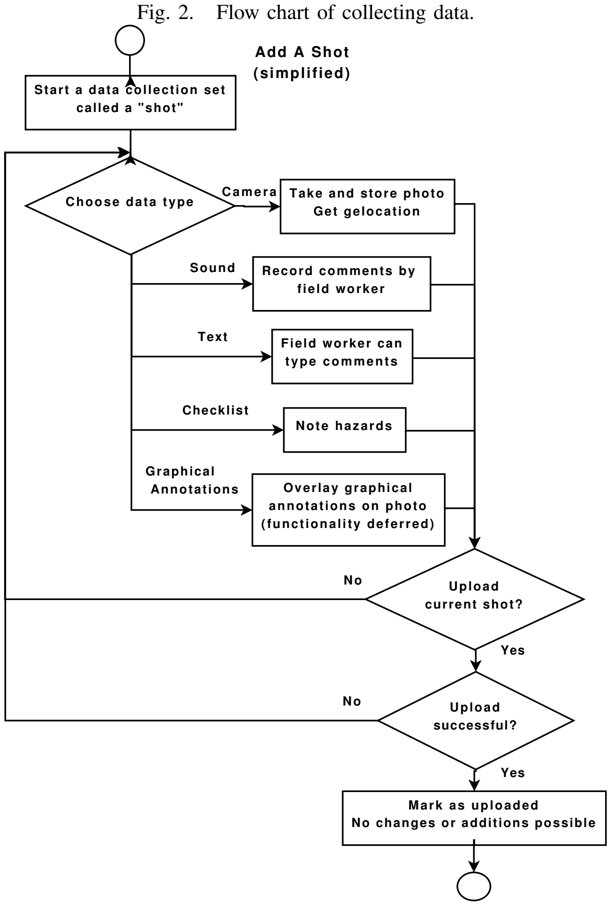
There are several operations available to the field worker, but the most important activity is collecting (and possibly uploading) a data set, or “shot”. A somewhat simplified view of this process is shown in Figure 2.

The other main operation initially available to the field worker is managing the collected shots. This allows the field worker to review the shots stored in the phone, upload any that have not yet been sent, and delete shots after uploading.

F. The supervisor’s view

The facilities initially available to the supervisor, whether on a mobile tablet or on a PC, are to search for available data, select a shot and to view (or listen to, in the case of sound) the data associated with that shot. The supervisor can choose to view a satellite or map view of the disaster area with the location of available shots overlaid. From this display, the supervisor can select which shot to examine. Alternatively, the supervisor can do a text-based search using as criteria a combination of date, location, and reported hazards.

Fig. 2. Flow chart of collecting data.



G. Security model

At first glance, it might seem that security is not a significant issue in this application. After all, the data gathering app will be provided only to designated individuals. However, there are (at least) three reasons why we must consider the question of security:

- Whenever one allows public access to a web site, one must expect frivolous or malicious uploads. These can range anywhere from irrelevant (and therefore time and resource wasting) to harmful and/or libelous.
- Some of the data captured may be of industrial sites or installations which the owners may consider private, and not wish to have available to public view.
- The damage being inventoried may be subject to insurance claims, and both the insurers and the insured may want the information to be private.

At the same time, we do not want to impose inconvenience or administrative overhead on the field workers. We have defined a security model in which new data will be accepted onto the server only from a known mobile device (regardless of which field worker is using it), and data will be available for inspection on the web based on a conventional web login process.

This model assumes that there is a way to reliably and invisibly know which phone sends each data upload. This need is met by an identification number which is created in each Android device when it is first powered up. These numbers are believed to be "almost unique". Each transmission to the server includes this identification number.

This model also assumes that the data are trustworthy regardless of who is using the phone. This may not be true even for legitimate users, and certainly is not true if the phone is stolen. We do record the user name of whoever submits the data, so in future, if we wish, we may try to detect which users send spurious data.

More significantly, however, all uploaded data sets are required to include a geotag which is acquired from the phone's location service. Because each known telephone id number is associated with a particular survey area, we can easily detect data sets uploaded from geographic locations which are not in the appropriate region.

H. Other considerations: Internet access

The system depends on the Internet for successful operation, yet Internet availability for mobile devices is problematic. Our design must handle the possibility that the Internet will not be reliably available to the mobile device, and also that the Internet speed might not always be fast enough for comfortable use.

Android mobile devices have two means of connecting to the Internet, both of which are wireless. Connecting via "wifi" is typically both fast and low-cost. However, it seems unlikely that wifi hotspots will be available in a disaster area. The alternative to wifi is connecting via the cellular network. At least in Thailand, this mode of access is widely available but variable both in reliability and speed.

The ideal mode of use for our system is for the field worker to immediately upload the data to the server. In this way the data are immediately available for use, and the non-trivial memory used on the mobile device can be immediately freed. However, the software alternatively permits the upload to be deferred if Internet connectivity is not available at a particular moment, or is so slow as to impair the effectiveness of the field worker.

I. Other considerations: Geotag validity

A second form of uncertainty during the operation of the system is the geotags. Android provides two methods for acquiring geographic position:

- From the cellular network. This is fast and cheap (assuming that the cellular network can be accessed). However, the location reported is actually the location of the cell tower currently tracking the phone, not of the device itself. Research has demonstrated that the location error based on Cell-ID is on the order of hundreds of meters [8].
- From GPS. This is the preferred source of information. GPS readings are far more accurate than Cell-ID localization and provide not only latitude and longitude but also elevation, bearing, and estimated accuracy. However, GPS signals are not always available.

Our system requires that the data be geotagged. If a current GPS geotag is not available, CrocScope will accept old information, up to a certain age, under the assumption that field workers will not be moving very fast. The metadata uploaded to the server includes information on both the age and source of the geotag.

IV. Status

There were three phases in the implementation of this project.

The first phase of our plan, development of the data gathering client and the data collection component on the server, has been completed on schedule. All of the capabilities for the mobile phone app, as described above, have been implemented except for the graphical annotation. The user interface, including a comprehensive user manual (rare in the mobile world), is available in English and Thai. Upload to the server works correctly, and the uploaded data is being correctly stored in the system database. The initial functionality for supervisor access to the server is also working, and the supervisor can view a satellite image of the disaster area.

At the time of this writing, we have just entered the second phase of the project. During this period the students in the field will be uploading data sets. Meanwhile the students at the university will be upgrading the software in response to user feedback and to incorporate functionality we have already specified but not yet completed.

As educators, we are very excited about this phase, because the students will have the opportunity to experience the evolution of a functioning, live system. However, we believe that the system, even as it exists now, is providing a valuable source of information for companies impacted by the floods.

V. Future plans

As noted in the introductory sections of this paper, the original goals of CrocScope were necessarily modest. After the immediate needs for situation status information are met, we expect to expand both the functionality of the system and its target audience.

We plan to add at least the following capabilities to the mobile application:

- Photo annotation capabilities, so users can circle problem areas, draw arrows, add small amounts of text, and so on.
- Better shot management capabilities, allowing users to go back and edit information for any shot, prior to uploading.
- A work tracking component, so users can start with a task list and check off each location as they visit and capture information about it.
- The ability to define and load custom forms for data entry, and also to customize the hazards check list. This will allow other organizations to modify the user interface and the data model to better meet their specific needs.

As soon as we are satisfied with the stability of the mobile app, we will make it available to other groups.

We also plan significant enhancements to the supervisor application, including an ability to use shots to define and track a remediation workflow.

VI. Conclusion

Over the past few years, researchers have been claiming that mobile geospatial applications will revolutionize the generation and use of geographic information. Our experiences suggest that there many obstacles to this optimistic scenario still exist. Mobile devices still have significant performance limitations. Unreliable GPS availability and wireless connectivity are serious issues.

The Android operating system, libraries and development tools, which are changing almost daily, suffer from version compatibility issues as well as outright bugs. Nevertheless, the fact that we were able to develop the CrocScope program to the point of usability within a few weeks testifies to the growing maturity of the Android software platform.

The CrocScope project represents software developed in an emergency situation to meet the immediate needs of disaster recovery. Although limited in scope, the project demonstrates the already impressive power of mobile devices and the potential of mobile software to transform the process of gathering and using spatial data. CrocScope is not a mobile GIS, but it is nevertheless a moderately complex mobile application, with almost a dozen screens. As CrocScope continues to evolve, along with the mobile ecosystem, we expect both its capabilities and its audience to expand.

References

[1] J. Camarero and C. A. Iglesias. Disasters 2.0. application of Web 2.0 technologies in emergency situations. In *Proceedings of the 6th International ISCRAM Conference*, Gothenburg, Sweden, May 2009.

[2] J. T. B. Fajardo and C. M. Oppus. A mobile disaster management system using the Android technology. *WSEAS Transactions on Communications*,9(6): 343–353.

[3] Z. Hemani, D. Culverhouse, R. Renner and H.S. Pio. Mobile geospatial applications for Android to aid in geocollaboration. In *COM.Geo '10 Proceedings of the 1st International Conference and Exhibition on Computing for Geospatial Research and Application*, Washington, DC, 2010.

[4] J. Lee, D.L. Niko, H. Hwang, Man. Park and C. Kim. A GIS-based design for a smartphone disaster information service application. In *Proceedings of First ACIS/JNU International Conference on Computers, Networks, Systems and Industrial Engineering (CNSI)*, Korea, 2011, pages 338–341.

[5] A. Savelyev, S. Xu, K. Janowicz, C. Mlligann, J. Thatcher and W. Luo. Volunteered geographic services: developing a linked data driven location-based service. In *SSO '11 Proceedings of the 1st ACM SIGSPATIAL International Workshop on Spatial Semantics and Ontologies*, Chicago, U.S.A., 2011.

[6] S. H. Seop, M. G. Young and J. D. Hoon.A study on the development of disaster information reporting and status transmission system based on smart phone. In *Proceedings of 2011 International Conference on ICT Convergence (ICTC)*, Korea, 2011, pages 722–726.

[7] W. Song and G. Sun. The role of mobile volunteered geographic information in urban management. In *Proceedings of 2010 18th International Conference on Geoinformatics*, China, 2010, pages 1–5.

[8] E. Trevisani and A. Vitaletti. Cell-ID location technique, limits and benefits: an experimental study. In *Proceedings of Sixth IEEE Workshop on Mobile Computing Systems and Applications*, United Kingdom, 2004, pages 51–60.

[9] United Nations Educational and Social Organization. UN lends full support for Thailand flood response. http://www.unescobkk.org/news/article/un-lends-full-support-for-thailand-flood-response/2011-11-22. Accessed 10 January 2011.

[10] A. N. Van, K. S. Oo and W. Takeuchi. Development of field survey software on Apple's iPhone and iPad for land use and land cover applications. In *Proceedings of the 32nd Asian Conference on Remote Sensing*, Taiwan, 2011.

[11] World Bank. The World Bank supports Thailand's post-floods recovery effort. http://go.worldbank.org/TCFEHXJML0. Accessed 10 January 2011.

[12] H. Zhong, P. Li, Y. Hu, Z. Lu, J. Yin, B. Yu and J. Wu. A solution for the data collection in the field survey based on Mobile and Wireless GIS. In *Proceedings of 2010 18th International Conference on Geoinformatics*, China, 2010.

[13] M. Zook, M. Graham, T. Shelton and S. Gorman. Volunteered geographic information and crowdsourcing disaster relief: a case study of the Haitian earthquake. *World Medical and Health Policy*, 2(2), pages 231–241, 2010.