A Personalized GeoSocial App for Surviving an Earthquake

Shlomo Bekhor
Technion
sbekhor@technion.ac.il

Sara Cohen
Hebrew University
sara@cs.huji.ac.il

Yerach Doytsher
Technion
doytsher@technion.ac.il

Yaron Kanza
Jacobs Institute, Cornell Tech
kanza@jacobs.cornell.edu

Yehoshua Sagiv
Hebrew University
sagiv@cs.huji.ac.il

ABSTRACT

Earthquakes are sudden, cause huge damage to extensive areas, and may negatively affect the lives of millions of people. Thus, it is crucial to develop a system that can help people survive an earthquake and recover from its aftereffects. In this paper we present a vision of a smartphone app, called EAGA (earthquake alerter and guidance app), that will guide both victims and rescue workers, by leveraging probabilistic geosocial information collected before the event, during the earthquake and in its aftermath. The app has four modes of operation. In *standby mode*, EAGA collects data about users, their regularly visited locations and their social relations. In *alert mode*, EAGA warns of an impending earthquake, based on data collected from a variety of sensors and from government warning systems. It also provides initial guidance to the user during the onset of the quake. In *disaster mode*, EAGA assists users to cope with the tasks of the immediate aftermath, such as evacuation and rescue of victims buried underneath rubble of collapsed buildings. Finally, in *recovery mode*, EAGA facilitates family reunification, provides information about aid centers and sends warnings regarding the spread of diseases. We believe that EAGA can revolutionize disaster management, and complements current earthquake readiness efforts, by allowing a large degree of much needed decentralization and personalization in dealing with earthquakes.

Categories and Subject Descriptors

H.2.8 [**Database Management**]: Database Applications—*Spatial databases and GIS*

Keywords

Disaster management system; earthquake-survival app

1. INTRODUCTION

Earthquakes are a grave threat to many countries—they are frequent, unexpected and can cause huge damage. Since earthquakes are unavoidable, it is essential to be prepared so that when an earthquake strikes, the number of casualties will be as low as possible, chaos will be minimized and recovery will be speedy. To that end, it is vital to warn people at the onset of a quake, to explain evacuation procedures and to guide them to shelter. Then, in the aftermath, it is essential to help people recover from the event by providing information and recommendations to survivors and by helping rescue workers locate earthquake victims.

Much effort has already been made by governments to prepare for earthquakes. However, this preparation typically takes a centralized view, e.g., by improving government warning systems, and by scheduling earthquake readiness exercises for rescue workers. In this paper we present a novel vision of an app that functions as a personal assistant during an earthquake and in its aftermath. Our app, called *EAGA (earthquake alerter and guidance app)*, provides individuals with user-specific alerts and guidance, personalized by their geographic location and social relations. In addition, EAGA allows information to flow from users, and then to be automatically aggregated together, to provide timely and precise information to rescue workers. Thus, EAGA complements current earthquake readiness efforts, by allowing a large degree of much needed decentralization and personalization in dealing with earthquakes.

The choice to develop a personal earthquake assistant specifically as a smartphone app (and not, for example, as a web-based system) is crucial. Smartphones are highly prevalent, even in developing countries, and are likely to become even more common in the upcoming years. They can often continue to operate even during a power outage. Due to their mobility and utility, people usually carry their smartphones, or keep them nearby, and hence, they are accessible in times of emergency. Finally, EAGA leverages the innate capabilities of a smartphone (e.g., cellular and WiFi networking, local storage, GPS, microphone, camera) and exploits these to help users survive an earthquake.

EAGA has four modes of operation. In *standby mode*, the app collects data about users, their regularly visited locations and their social relations. It also collects government provided information about building and road stability, for the areas in which the user frequents. The data are stored locally and on a remote server, only to be used in case of an emergency. In *alert mode*, the app warns of an impending earthquake, based on data collected from a variety of sensors and from government warning systems. It also provides initial guidance to the user during the onset of the quake. In *disaster mode*, the app assists users to cope with the tasks

EM-GIS'15, November 03-06, 2015, Bellevue, WA, USA
ACM 978-1-4503-3970-4/15/11 ...$15.00.
DOI: http://dx.doi.org/10.1145/2835596.2835616.

of the immediate aftermath, such as evacuation and rescue of victims buried underneath rubble of collapsed buildings. Finally, in *recovery mode*, the app facilitates family reunification, provides information about aid centers and sends warnings regarding the spread of diseases. Each of these modes are discussed in detail later on.

The following example illustrates the EAGA approach.

EXAMPLE 1.1. *Consider the following hypothetical earthquake scenario. Stewart Gaff, and his wife Remy,*[1] *are residents of Los Angeles, who installed EAGA. For several years, EAGA was in standby mode, and collected information about the places they frequently visit and their social relationships.*

When an earthquake struck, EAGA went into alert mode, sensed the initial tremor and instructed Stewart to find cover under his desk, as the estimated time to leave the building was too long. This saved his life, but, as the building collapsed, Stewart found himself trapped beneath the rubble. The app went into disaster mode, allowing Stewart to send a message with his geographical coordinates, indicating that he is alive and trapped, as well as a picture of his condition. This message was automatically directed both to his nearest and dearest (according to the previous collected social information), as well as to rescue teams in the vicinity. Without such app, it would have been too difficult for Stewart, being injured and trapped, to send such message.

At the time the quake struck, Remy was driving to her office. In alert mode, her app instructed her to pull over to the side of the road just before the main quake struck. Then, immediately after the quake, in disaster mode, the app provided Remy with a route to the school of her children and from there, out of the city, allowing her and other people to use all the lanes to get away from the danger zone. Remy also took with her two friends of her children, whose parents still had not shown up.

Still in disaster mode, both Remy's EAGA installation, as well as that of rescue teams, received information about where Stewart was buried. The rescue teams were also provided with aggregated estimations about how many other people were trapped in the collapsed building. Such statistics were based both on real-time information, as well as on information collected during the standby mode.

In the following days, in recovery mode, the app assisted Remy in finding shelter and aid, as well as in finding the parents of the children she took with her during the school evacuation. When Stewart was discovered, barely alive, he was identified using the app, which also recognized that Remy was his closest relation. Therefore, a message stating where Stewart was hospitalized was sent to Remy.

Example 1.1 illustrates how an earthquake guidance and alert app can save lives, and help in earthquake recovery. This greatly differs from current, so-called, earthquake apps that merely provide information about earthquakes around the globe, but do not supply personalized guidance. We note that the true power of EAGA lies in its ability to gather critical information before a quake (during standby mode), and then to fully leverage this data when the quake occurs.

Various disaster (emergency) management systems have been developed [1,4,11,34,36] and some are already in use, e.g., Sahana [5]. However, these systems are web-based, unlike the EAGA personalized app approach. Using data collected from the crowd to assist in emergency situations also received attention [3,20,33,41,49]. It has been shown how to utilize social networks for distribution of data, in emergency situations [17,26] and in aiding family reunification after a disaster [40]. These systems mostly consider data collected at the time of the emergency, but do not leverage geosocial information gathered beforehand. Several papers studied the effect of earthquakes on social networks, on microblogging and on the Internet [7,18,37,42,44,45,47], and the use of social media in recovery from an earthquake [19,50]. The effect on electronic communication has been considered as well [27]. The effectiveness of the Internet as a communication method to provide information after an earthquake has been illustrated [27,37,45].

All the above works differ significantly from the EAGA approach. Our main contributions in this vision paper are

- introducing the concept of a personal alert and guidance app for earthquakes,
- utilizing historical data about people in the form of spatio-temporal and social distribution functions,
- extensive real-time use of geosocial data (data about people with both a spatial and a social aspect [12]),
- outlining the main functionality of the system in its four special modes.

EAGA is an open-ended system, with numerous options for extension beyond those presented, particularly towards other types of disaster management, and we believe that, when implemented, EAGA will have a far-reaching positive effect on earthquake management and recovery.

2. THE DATA MODEL

In order to achieve its goals, EAGA gathers data of various types, at different points in time. In particular, both personal data, based on user activity, as well as data provided by official sources, is collected. This data can be geographic, social or textual in nature. The data is accumulated before the quake, during the quake and in its aftermath.

In general, all information has some degree of uncertainty. In addition, it is important that the system leverage all information it has, but also degrade gently, and still allow a maximum degree of effectiveness when some information is not available. This is critical, since past experience with earthquakes shows that the least amount of information comes from the most severely hit areas. Therefore, it is crucial that some information be automatically sent from mobile phones and wearable devices. This necessitates hardening of the mobile-network infrastructure so that (at least) data packets can be transmitted under all circumstances.

Before discussing the specific types of data gathered, we note that all such information should be classified according to the following five criteria:

- *relevance*, i.e., whether the information can be helpful in accomplishing EAGA's goals,
- *specificity*, e.g., damage to a bridge vs. an assessment of which types of vehicles can still cross the bridge,

[1]The names are based on the leading characters of the movie *Earthquake* (1974).

- *validity*, i.e., the time interval in which information is valid, until it is superseded by a more recent report or some action has taken place,
- *importance*, e.g., helpful vs. live-saving information,
- *urgency*, i.e., whether the information should be acted upon immediately or within a specific time period.

Classifying information with these criteria is important to help users and rescue teams focus on specific information, within the sea of data generated in a quake. We discuss the main types of data considered next.

Probabilistic Geographical Data. EAGA will support several types of probabilistic geospatial data. The first such type is *a spatial-temporal distribution*, which associates with a given user a probabilistic description of where the user is likely to be at different points in time. Thus, the spatial-temporal probability distribution function of a person p, associates pairs (l, i), where l is a location, and i is a time interval, with the probability that p is in l during interval i. For example, such a distribution may indicate that on business days, with probability 0.9, at 8-9AM Stewart is at home, and with probability 0.1, Stewart is in transit on his way to work. Such a spatial-temporal distribution provides an estimation of where Stewart is, in case of an earthquake that strikes between 8 and 9AM, on a workday. Such information can be used in a case where during the quake, the cellular phone is damaged and cannot transmit the location of the user. An important challenge that must be met by EAGA is that of effectively learning the spatio-temporal distribution of a user, as she moves about over time.

Another important type of probabilistic geographic information is the estimated condition of locales, both at present, and in the future (should an earthquake strike). The former data can be derived by aggregating information provided explicitly or implicitly by users (such as notifications of a bridge collapse, or observations that users avoid a bridge), while the latter data will typically be provided by the government (e.g., via simulations that predict the extent of damage to buildings if an earthquake hits nearby).

Probabilistic Social Relations. In order to allow notifications to be sent to friends and relatives, as well as to facilitate family reunification, social relationships must be known to EAGA. Such data often cannot be provided a priori, upon installation, as earthquakes are rare, and thus, previously provided data can become outdated. Instead, EAGA collects probabilistic information about social relationships autonomously (during standby mode), e.g., based on the frequency of phone calls between people, the association of several phone numbers with the same plan of the cellular company, or associating people when they are at the same place frequently. Much of this information is private and should only be used in severe cases of emergency, such as in the aftermath of an earthquake.

Geo-Textual Data. Geo-textual data is critical when dealing with an earthquake. Intuitively, geo-textual data is simply text that is association with a geographic area [39], using geo-tags or by inference [15,23]. Such textual data will often be provided by official rescue teams, and must be disseminated to those in problem areas. Similarly, geo-textual data will be generated by users, and must be aggregated and sent to rescue teams, in order to notify them of problems in different locations.

3. THE FOUR MODES OF EAGA

We describe the different modes of EAGA, the functionality the app should support in each mode, and their utility. EAGA provides a comprehensive solution by binding the four modes of operations, however, each mode also has a merit of its own when used independently.

3.1 Standby Mode

To deal with the chaos caused by a high-magnitude earthquake, it is essential to use all available information. Thus, in standby mode (i.e., from the time of installation until an earthquake occurs), EAGA collects data about the normal behavior of users, and their social relations [8,9], while operating in the background, e.g., gather spatial-temporal distributions of visited locations [29] and probabilistic information about social relations as well as statistical properties of users in the social network [31]. EAGA also collects geographic information from official sources as to expected earthquake dangers (e.g., from simulations) [35], as well as information about traffic in ordinary (non-emergent) cases [32], etc. The different types of data gathered were discussed in more detail in Section 2. The main challenges of standby mode are to keep the information up-to-date, e.g., as user habits and relations evolve, and to compactly store relevant information (e.g., see [21, 22]) in a private manner. In addition, all this must be accomplished while minimizing the required system resources, so as not to degrade other apps that are running in parallel.

3.2 Alert Mode

The first few seconds of an earthquake are critical. It is vital to alert people as soon as possible and to direct them to shelter or to the safest place in their vicinity. To this end, the app should initially detect the earthquake. This can be done using the accelerometer of the device, to detect tremors that precedes the main quake, by connecting to a national or international earthquake early alert system (a system that detects seismic activity and sends an alert) [2, 25] and using social media [10, 14, 44]. EAGA can integrate sensor data from various sensors to increase the accuracy of the detection [38]. The alert mode should take into account the location of the user and should not rely on the accelerometer in places where false alarms is common, e.g., an amusement park in which some rides mimic a quake or when the user is on a boat.

At the time of the alert, the user has only a few seconds to find cover. The system should guide the user, using voice instructions, based on the location of the user. Thus, EAGA must choose the correct geo-textual information to display to the user, based on her precise location. If the user is inside a building, EAGA will choose a message instructing the user to evacuate the premises (if the user can leave quickly enough) or to find cover in the building, e.g., under a desk. If the user is driving, EAGA will choose a message that instructs the user to pull over, unless she is on a bridge or in a tunnel and can drive to a safer place before the main quake. In case of a user in an open area, EAGA will instruct the user to get away from buildings and especially from old buildings that were not designed to sustain an earthquake.

To accomplish all this effectively in real-time, EAGA must quickly determine the user's location, and find the most specific and most relevant geo-textual information. Note that EAGA degrades gracefully when information is missing by displaying a generic message from the home-front command.

3.3 Disaster Mode

Immediately after the quake, users may be trapped in debris, or free to escape but surrounded by wreckage. It is of utmost importance to rescue trapped victims and to guide others to get away from the danger zones. To compute effective escape routes, EAGA leverages both the spatial data and the social data of the victims [13]. In many cases, it is important to distribute information about hazards or allow victims to call for medical help. All this requires managing geospatial data, and presenting to users only relevant information, based on their location or the location of their loved ones. We present some of the main features of EAGA.

Trapped People. EAGA tries to detect if the user is trapped, based on its location (e.g., by determining whether the phone is in a place where a building used to stand vs. an open area). The user can also interact directly with EAGA (if she is conscious) to state her condition. If, with significant probability, it seems that the user is trapped or unresponsive, an initial message will be sent automatically to an emergency center in the vicinity and to the relatives of the person, as determined by the probabilistic social relations. For handling commutation issues and problems, see [27]. EAGA will remotely activate the microphone and camera of the phone, for a short duration, to better asses the user's status. It can also emit intermittent loud beeps to help rescue workers locate the user within the rubble. To prevent errors, EAGA allows users to report the lost of their device from any other device to prevent cases where rescue teams dig to rescue buried lost phones.

Evacuation Planning. Victims who are not trapped and can leave the danger zone should do so as quickly and as safely as possible. EAGA will suggest evacuation routes for the users while taking into consideration all known (or probabilistic) geographic information. Some such information will be provided by official organizations, while other data will be derived from the users explicitly or implicitly by observing traffic trends. Unlike the wealth of previous work on evacuation route computation [16], during an earthquake many users will choose to first move towards their dependents (e.g., children), before fleeing from the hazardous area. Thus, evacuation plans in the aftermath of an earthquake must take this into consideration in planning routes, and also in determining expected congestion [6]. One option to *search dependents and flee* is by setting presumed locations of dependents, shelters and safe areas as goals and planning a route via these goals, similarly to the route computation in [24, 28, 43]. Other options should be explored.

It is extremely important to assess the condition of transportation infrastructures, such as roads, bridges and tunnels. To guide users, EAGA must know which places can serve as temporary shelters for escaping populations. Again, in addition to relying on reports from individuals and organizations, EAGA will actively learn about blocked roads by monitoring the traffic, and about safe shelter areas by detecting places from which many people send soothing messages to their relatives. Combining implicit and explicit information is crucial to achieve effective evacuation planning.

Information Dissemination. During an earthquake, information is crucial and can save lives. However, when huge amounts of data are generated, it can be difficult for users to focus on the most pertinent information. EAGA disseminates geo-textual data to users, according to their expected interest, e.g., information will be sent to a user about locations that she frequents (according to her spatial-temporal distribution), about locations of her friends (according to her probabilistic social relations) and about her close vicinity. Leveraging data classification (as to importance, relevance, and urgency) allows EAGA to decide on the order in which messages should be sent.

3.4 Recovery Mode

In the days after the quake, EAGA will help teams in recovery missions, such as family reunification and aggregating information for the benefit of rescue teams (e.g., to help locate buried people, deliver medical care to victims [46], and monitor the spread of diseases [30, 48]).

Family Reunification. For a given person p, family reunification involves two components: *(1)* finding a close relative r of p and *(2)* computing a safe path for p to reach r. The latter task was discussed above, in evacuation planning. The former task can easily be accomplished if p is able to speak and state who her closest relatives are. If this is not possible (e.g., p is severely injured, is a baby or has Alzheimer's disease) EAGA searches for likely acquaintances and relatives of p by using the spatial temporal distribution of other users to find those that are likely to have come in contact with p. Another option would be to integrate EAGA with Google Person Finder[2] to help users find one another.

Aggregating Information. As we have already discussed, with the EAGA app, information about individual user is generated. Such information will include locations of trapped people (as mentioned above), as well as other notices that users can send (e.g., about their injuries or disease). Such information will be aggregated, and displayed visually for rescue teams, so that resources can be allocated, and epidemics can quickly be detected.

4. CONCLUSION

We presented a novel type of earthquake alert and assistance app that collects necessary information before the earthquake and during the event, alerts people when the earthquake starts, guides victims and rescue teams in the aftermath, provides information about where people might be buried, indicates hazards and calculates safe evacuation routes. The novelty of our approach is in utilizing spatio-temporal probability distribution functions, social relationships, and real-time geo-textual data to detect events, indicate hazards and predict needs and movement of people. Due to the severity and frequency of earthquakes around the globe, we believe EAGA could help save lives, and the approach could be adapted to other types of scenarios and other disaster-management systems.

[2]`www.google.org/personfinder/global/home.html`

5. ACKNOWLEDGMENTS

This research was supported in part by the Israeli Ministry of Science and Technology (Grant 3-9617) and by the Israel Science Foundation (Grant 1467/13). Yaron Kanza is currently a researcher at AT&T.

6. REFERENCES

[1] J. Abrahams. Disaster management in australia: The national emergency management system. *Emergency Medicine*, 13(2):165–173, 2001.

[2] J. E. Aranda, A. Jimenez, G. Ibarrola, F. Alcantar, A. Aguilar, M. Inostroza, and S. Maldonado. Mexico city seismic alert system. *Seismological Research Letters*, 66(6):42–53, 1995.

[3] L. I. Besaleva and A. C. Weaver. Applications of social networks and crowdsourcing for disaster management improvement. In *Proc. of the 2013 International Conf. on Social Computing*, SOCIALCOM '13, pages 213–219. IEEE Computer Society, 2013.

[4] M. Careem, C. De Silva, R. De Silva, L. Raschid, and S. Weerawarana. Sahana: Overview of a disaster management system. In *Information and Automation, 2006. ICIA 2006. International Conference on*, pages 361–366. IEEE, 2006.

[5] M. Careem, C. De Silva, R. De Silva, L. Raschid, and S. Weerawarana. Demonstration of sahana: free and open source disaster management. In *Proc. of the 8th annual international Conf. on Digital government research: bridging disciplines & domains*, pages 266–267. Digital Government Society of North America, 2007.

[6] L. Chittaro and D. Nadalutti. Presenting evacuation instructions on mobile devices by means of location-aware 3d virtual environments. In *Proc. of the 10th International Conf. on Human Computer Interaction with Mobile Devices and Services*, pages 395–398. ACM, 2008.

[7] K. Cho, C. Pelsser, R. Bush, and Y. Won. The japan earthquake: the impact on traffic and routing observed by a local isp. In *Proc. of the Special Workshop on Internet and Disasters*, SWID '11, pages 2:1–2:8. ACM, 2011.

[8] S. Cohen and N. Cohen-Tzemach. Implementing link-prediction for social networks in a database system. In *Proc. of the ACM SIGMOD Workshop on Databases and Social Networks*, pages 37–42, New York, 2013.

[9] S. Cohen and A. Zohar. An axiomatic approach to link prediction. In *Proc. of the Twenty-Ninth AAAI Conference on Artificial Intelligence, January 25-30, 2015, Austin, Texas, USA.*, pages 58–64, 2015.

[10] A. Crooks, A. Croitoru, A. Stefanidis, and J. Radzikowski. # earthquake: Twitter as a distributed sensor system. *Transactions in GIS*, 17(1):124–147, 2013.

[11] P. Currion, C. d. Silva, and B. Van de Walle. Open source software for disaster management. *Commun. ACM*, 50(3):61–65, Mar. 2007.

[12] Y. Doytsher, B. Galon, and Y. Kanza. Querying geo-social data by bridging spatial networks and social networks. In *Proc. of the 2nd ACM SIGSPATIAL International Workshop on Location Based Social Networks*, LBSN '10, pages 39–46. ACM, 2010.

[13] Y. Doytsher, B. Galon, and Y. Kanza. Storing routes in socio-spatial networks and supporting social-based route recommendation. In *Proc. of the 3rd ACM SIGSPATIAL International Workshop on Location-Based Social Networks*, pages 49–56, Chicago, Illinois, 2011.

[14] P. Earle. Earthquake twitter. *Nature Geoscience*, 3(4):221–222, 2010.

[15] D. Flatow, M. Naaman, K. E. Xie, Y. Volkovich, and Y. Kanza. On the accuracy of hyper-local geotagging of social media content. In *Proc. of the Eighth ACM International Conf. on Web Search and Data Mining*, WSDM '15, pages 127–136, Shanghai, China, 2015.

[16] S. Fraser, G. Leonard, I. Matsuo, and H. Murakami. *Tsunami evacuation: lessons from the Great East Japan earthquake and tsunami of March 11th 2011.* GNS Science, 2012.

[17] L. Frommberger and F. Schmid. Mobile4d: Crowdsourced disaster alerting and reporting. In *Proc. of the Sixth International Conf. on Information and Communications Technologies and Development: Notes - Volume 2*, ICTD '13, pages 29–32, New York, NY, USA, 2013. ACM.

[18] K. Fukuda, M. Aoki, S. Abe, Y. Ji, M. Koibuchi, M. Nakamura, S. Yamada, and S. Urushidani. Impact of tohoku earthquake on r&e network in japan. In *Proc. of the Special Workshop on Internet and Disasters*, SWID '11, pages 1:1–1:6. ACM, 2011.

[19] H. Gao, G. Barbier, and R. Goolsby. Harnessing the crowdsourcing power of social media for disaster relief. *IEEE Intelligent Systems*, 23(3):10–14, 2011.

[20] H. Gibson, S. Andrews, K. Domdouzis, L. Hirsch, and B. Akhgar. Combining big social media data and fca for crisis response. In *Proc. of the 2014 IEEE/ACM 7th International Conf. on Utility and Cloud Computing*, UCC '14, pages 690–695. IEEE Computer Society, 2014.

[21] R. Gotsman and Y. Kanza. Compact representation of GPS trajectories over vectorial road networks. In *Proc. of the 13th International Conf. on Advances in Spatial and Temporal Databases*, pages 241–258, Munich, Germany, 2013. Springer-Verlag.

[22] R. Gotsman and Y. Kanza. A dilution-matching-encoding compaction of trajectories over road networks. *GeoInformatica*, 19(2):331–364, 2015.

[23] I. Grabovitch-Zuyev, Y. Kanza, E. Kravi, and B. Pat. On the correlation between textual content and geospatial locations in microblogs. In *Proc. of Workshop on Managing and Mining Enriched Geo-Spatial Data*, GeoRich'14, pages 3:1–3:6, Snowbird, UT, USA, 2007. ACM.

[24] I. Hefez, Y. Kanza, and R. Levin. Tarsius: A system for traffic-aware route search under conditions of uncertainty. In *Proc. of the 19th ACM SIGSPATIAL International Conf. on Advances in Geographic Information Systems*, Chicago, Illinois, 2011.

[25] S. Horiuchi, H. Negishi, K. Abe, A. Kamimura, and Y. Fujinawa. An automatic processing system for broadcasting earthquake alarms. *Bulletin of the Seismological Society of America*, 95(2):708–718, 2005.

[26] P. T. Jaeger, B. Shneiderman, K. R. Fleischmann, J. Preece, Y. Qu, and P. Fei Wu. Community response grids: E-government, social networks, and effective emergency management. *Telecommun. Policy*, 31(10-11):592–604, Nov. 2007.

[27] H.-C. Jang, Y.-N. Lien, and T.-C. Tsai. Rescue information system for earthquake disasters based on manet emergency communication platform. In *Proc. of the 2009 International Conf. on Wireless Communications and Mobile Computing: Connecting the World Wirelessly*, pages 623–627. ACM, 2009.

[28] Y. Kanza, E. Safra, and Y. Sagiv. Route search over probabilistic geospatial data. In *Proc. of the 11th International Symposium on Advances in Spatial and Temporal Databases*, SSTD '09, pages 153–170, Aalborg, Denmark, 2009. Springer-Verlag.

[29] Y. Kanza and H. Samet. An online marketplace for geosocial data. In *Proc. of the 23rd ACM SIGSPATIAL International Conf. on Advances in Geographic Information Systems (SIGSPATIAL)*, Seattle, Washington, 2015.

[30] S. Karmakar, A. S. Rathore, S. M. Kadri, S. Dutt, S. Khare, and S. Lal. Post-earthquake outbreak of rotavirus gastroenteritis in kashmir (india): An epidemiological analysis. *Public Health*, 122(10):981–989, 2008.

[31] R. Levin and Y. Kanza. Stratified-sampling over social networks using mapreduce. In *Proc. of the 2014 ACM SIGMOD International Conf. on Management of Data*, pages 863–874, Snowbird, Utah, USA, 2014.

[32] R. Levin and Y. Kanza. Tars: Traffic-aware route search. *Geoinformatica*, 18(3):461–500, 2014.

[33] J. Li, Q. Li, C. Liu, S. Ullah Khan, and N. Ghani. Community-based collaborative information system for emergency management. *Comput. Oper. Res.*, 42:116–124, 2014.

[34] A. Mansourian, A. Rajabifard, M. V. Zoej, and I. Williamson. Using sdi and web-based system to facilitate disaster management. *Computers & Geosciences*, 32(3):303–315, 2006.

[35] T. M. McLaren, J. D. Myers, J. S. Lee, N. L. Tolbert, S. D. Hampton, and C. M. Navarro. Maeviz: An earthquake risk assessment system. In *Proc. of the 16th ACM SIGSPATIAL International Conf. on Advances in Geographic Information Systems*, Irvine, California, 2008.

[36] D. Mendonça, T. Jefferson, and J. Harrald. Collaborative adhocracies and mix-and-match technologies in emergency management. *Commun. ACM*, 50(3):44–49, Mar. 2007.

[37] M. Miyabe, A. Miura, and E. Aramaki. Use trend analysis of twitter after the great east japan earthquake. In *Proc. of the ACM 2012 Conf. on Computer Supported Cooperative Work*, CSCW '12, pages 175–178. ACM, 2012.

[38] M. Olson, A. Liu, M. Faulkner, and K. M. Chandy. Rapid detection of rare geospatial events: Earthquake warning applications. In *Proc. of the 5th ACM International Conf. on Distributed Event-based System*, DEBS '11, pages 89–100, New York, 2011.

[39] B. Pat, Y. Kanza, and M. Naaman. Geosocial search: Finding places based on geotagged social-media posts. In *Proc. of the 24th International Conf. on World Wide Web*, Florence, Italy, 2015.

[40] G. Pearson, M. Gill, S. Antani, L. Neve, G. Miernicki, K. Phichaphop, A. Kanduru, S. Jaeger, and G. Thoma. The role of location for family reunification during disasters. In *Proc. of the First ACM SIGSPATIAL International Workshop on Use of GIS in Public Health*, HealthGIS '12, pages 11–18. ACM, 2012.

[41] D. Pohl, A. Bouchachia, and H. Hellwagner. Automatic sub-event detection in emergency management using social media. In *Proc. of the 21st International Conf. on World Wide Web*, pages 683–686. ACM, 2012.

[42] Y. Qu, C. Huang, P. Zhang, and J. Zhang. Microblogging after a major disaster in china: a case study of the 2010 yushu earthquake. In *Proc. of the ACM 2011 Conf. on Computer supported cooperative work*, CSCW '11, pages 25–34. ACM, 2011.

[43] E. Safra, Y. Kanza, N. Dolev, Y. Sagiv, and Y. Doytsher. Computing a k-route over uncertain geographical data. In *Proc. of the 10th International Conf. on Advances in Spatial and Temporal Databases*, SSTD'07, pages 276–293, Boston, MA, USA, 2007. Springer-Verlag.

[44] T. Sakaki, M. Okazaki, and Y. Matsuo. Earthquake shakes twitter users: real-time event detection by social sensors. In *Proc. of the 19th international Conf. on World Wide Web*, pages 851–860. ACM, 2010.

[45] A. Sarcevic, L. Palen, J. White, K. Starbird, M. Bagdouri, and K. Anderson. "beacons of hope" in decentralized coordination: learning from on-the-ground medical twitterers during the 2010 haiti earthquake. In *Proc. of the ACM 2012 Conf. on Computer Supported Cooperative Work*, CSCW '12, pages 47–56. ACM, 2012.

[46] C. H. Schultz, K. L. Koenig, and R. J. Lewis. Decisionmaking in hospital earthquake evacuation: does distance from the epicenter matter? *Annals of emergency medicine*, 50(3):320–326, 2007.

[47] A. Utani, T. Mizumoto, and T. Okumura. How geeks responded to a catastrophic disaster of a high-tech country: rapid development of counter-disaster systems for the great east japan earthquake of march 2011. In *Proc. of the Special Workshop on Internet and Disasters*, SWID '11, pages 9:1–9:8. ACM, 2011.

[48] D. A. Walton and L. C. Ivers. Responding to cholera in post-earthquake haiti. *New England Journal of Medicine*, 364(1):3–5, 2011.

[49] D. Yates and S. Paquette. Emergency knowledge management and social media technologies: A case study of the 2010 haitian earthquake. *Int. J. Inf. Manag.*, 31(1):6–13, Feb. 2011.

[50] D. Yates and S. Paquette. Emergency knowledge management and social media technologies: A case study of the 2010 haitian earthquake. *International Journal of Information Management*, 31(1):6–13, 2011.