The dynamics of a virtual community during a natural disaster: a network analysis

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Abstract: Online discussion forums are computer-mediated social networks where individuals self-organise to help each other and share knowledge, advice, and perspectives about their common interests. The present study empirically examines the dynamics and changes to the properties and structure of an electronic network based on an online forum during a massive earthquake. This study found that the open, fluid electronic network allowed members easily to join and participate in the forum communication. The communication links and the numbers of initiators and repliers increased during the earthquake. We also found that network density and reciprocity decreased along with the network growth, while the average shortest path length increased. This research provides a framework to study dynamics and changes of electronic networks.

Keywords: virtual community; network analysis; earthquake disaster.

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1 Introduction

A massive 8.0-magnitude earthquake struck Wenchuan, Sichuan province in China on May 12, 2008. This catastrophic disaster killed nearly 70,000 people and displaced up to 10 million. The 5.12 Wenchuan earthquake shocked everyone. People reached out to each other via many communication tools. Individuals sought support and exchanged information through online communities, such as mailing lists, chat rooms, and discussion forums. They passed along breaking news, reported rescue progress, and sent on-site pictures and videos. They also shared their personal experiences, wrote detailed eyewitness descriptions and shared tender words of comfort. Online communities and discussion forums constituted a useful proxy for the underlying communication networks during the 5.12 earthquake.

The empathy and shared reflection brought people across barriers of time, distance, and culture together via online communities during this disaster. Communication and a spirit of collaboration can help strengthen any community, online or offline. How the online communities were impacted by the disaster is of importance to both academics and practitioners. This study will investigate the dynamics and change of communication network structure in an online discussion forum before and after the earthquake.

Network analysis is often used to discover patterns of interaction between actors in a social network, such as network centralisation and network density. Network analysis can help us discern communication patterns and understand network dynamics in ongoing processes of the online forum communication. Based on longitudinal data of a student online forum communication, the paper attempts to analyse the network structure and the pattern changes associated with a natural disaster.

Based on the theoretical perspectives on disaster crises proposed by network theorists and sociologists, we test several key propositions on the changes in the network communication structure. These propositions relate to network growth, density, reciprocity, diameter, and average shortest path length.

This paper is organised as follows: the research significance is presented in the next section. The explanation of network measures and hypotheses are developed in the following section. Section 4 is the research methodology, including collecting a forum dataset and creating social matrix from the dataset. Section 5 presents the network analysis results and hypothesis testing. Finally, Section 6 is the discussion of the results and their implications.

2 Research setting and significance

The impact of crises on human behaviour has most frequently been studied in the context of natural disasters. Researchers have examined individual-level responses to disaster warning, the impact of the occurring disaster on social and psychological functioning, the effects of relocation, and the return to normalcy (Perry and Mushkatel, 1984). Rogers and Sood (1981) examine the functioning of mass media during natural disasters. Previous studies have largely treated emergency services organisations, such as police, fire, civil defense, and Red Cross, as sources of aid to disaster-struck communities (Danowski and Edison-Swift, 1985). Given the potent and dynamic capability of social networks in communicating and sharing information, using social networks for disaster management and recovery has recently attracted the attention of scholars and government agencies (Kapucu, 2006; Palen et al., 2007). Social networks allow for rapid pooling of information and knowledge to handle unexpected events (Lu and Yang, 2011) and offer flexible crisis intervention to address "irreducible uncertainty and imperfect knowledge" (Weick et al., 1999).

Traditionally, network analysis focuses on the whole and static network structure. Monge and Contractor (2003, p.325) comment on social network analysis and point out "almost all SNA research is static and cross-sectional rather than dynamic". This methodology denies the dynamic nature of social relationship and cannot analyse the inherent network formation processes (Emirbayer, 1997). As a result, the traditional methods are inadequate for measuring the effectiveness of online networks in the context of disasters due to the nascent nature of the ecosystem of online social systems. Overall, little attention has been given to the network levels of analysis, such as the organisational or community level, during a crisis. Little is known about communities as end recipients of disaster effects. This study empirically examines the dynamics and changes of the properties and structure of an online communication network during a disaster strike. By capturing daily communication data from an online forum and empirically examines the online community network structure by investigating its ongoing dynamics through three different periods: before the earthquake, during the earthquake, and after the earthquake, this research enhances existing research methods and creates new insights on the dynamic properties of electronic networks.

Online discussion forums are one of the most pervasive forms of electronic social networks. Electronic social networks support computer-mediated communications and create electronic links among thousands of individual members regardless of their physical locations or personal acquaintance. This study focuses on an internet-based discussion forum, where individuals discuss topics of interest to them and social ties are built through the discussions. Individuals may choose to act as silent viewers or active contributors to these discussions.

The communication through the online forum increased dramatically during the earthquake period, and lasted for about three weeks (from May 12 to June 1). To illustrate the changing of forum communication, we also collected data for pre-earthquake period (the three weeks before May 12), and post-earthquake period (the three weeks after June 1).

Danowski and Edison-Swift (1985) list several major advantages of using computer-based communication data: studying naturally occurring social units; observing communication processes over time; and automatically capturing valid and reliable data. The availability of the student's online forum archive has emerged as an important resource for studying a range of organisational dimensions as impacted by the changing communication network structure. The naturalistic examination of an online community communication dynamics provides new insights on the dynamics of social network formations and evolutions during a natural disaster.

3 Network topology and hypotheses

The study of networks has a long history in mathematics and the sciences. Historically, the study of networks has been mainly the domain of a branch of discrete mathematics known as graph theory. Social network analysis started to develop in the early 1920s and focuses on relationships among social entities, trades among nations, or communication between members. In the past few years, we have witnessed dramatic advances in the study of complex networks. This type of study moves the focus of analysis from small networks to systems with thousands or millions of nodes, with an emphasis on network dynamics and changing over time.

The topological properties of networks help us study the network as a whole instead of studying the individual constituents. These topological properties include network growth, network density, reciprocity, and average shortest-path length. Based on the properties, we develop hypotheses for the impact of the disaster on the social networks and online community communication.

3.1 Network growth

Most real-world networks are not static and they grow by adding nodes and links. For instance, the World Wide Web grows exponentially by the addition of new web pages, and a co-authorship network grows by the addition of collaborators. The growth leads to changes in the topological characteristics of the networks. Barabâsi and Albert (1999) identify growth as one of the important ingredients in the evolution of a scale-free network.

During an emergency, both the need for information and the new information created will increase dramatically. When a disaster leads to the sudden change in reality, both individuals and social units need new information to orient their actions. For social units representing the community, this may mean damage assessment of what actually happened. For individuals, they need to gather information so that they may take preventative or rescue actions. All these activities will add more individuals to the network and create new information for sharing in a network. Therefore, we offer the first two propositions:

Proposition 1 The numbers of communication nodes (n) will be different in the three periods.

$H_o: \mu_{n1} = \mu_{n2} = \mu_{n3}$

H_a: at least two node means in the three periods are different,

where μ_{n1} represents the node mean of the pre-earthquake period (P1), μ_{n2} represents the node mean of the earthquake period (P2), and μ_{n3} represents the node mean of the post-earthquake period (P3).

Proposition 2 The numbers of communication links (l) will be different in the three periods.

$H_o: \mu_{l1} = \mu_{l2} = \mu_{l3}$

H_a: at least two link means in the three periods are different,

where μ_{l1} μ_{l2}, and μ_{l3} represent the link means for the periods P1, P2, and P3, respectively.

3.2 Network density

Network density is a measure of the incidence of direct relations among the possible pairs of a network. It is the ratio of the number of ties versus the maximum possible ties for a network (Wasserman and Faust, 1994). Network density (Δ) = 2 L / N (N – 1), where L is the number of links in the network, and N is the total number of nodes in the network. Network density indicates how nearly a network is complete – a state in which each member is connected directly with every other member.

The implication of network density is that when the relationships among a group of people are dense, that is, when a large proportion of the members of the network know each other, then the network as a whole is relatively compact and relatively few links between the persons need to be used to reach majority (Mitchell, 1969). Blau (1977) suggest that network density reflects group cohesion and intra-group bonds. When a community network faces a disaster, the community will increase in collaboration and cooperation and exhibit greater group cohesion and network density. This leads to the third proposition:

Proposition 3 The network density (Δ) will be different in the three periods.

$H_o: \mu_{\Delta 1} = \mu_{\Delta 2} = \mu_{\Delta 3}$

H_a: at least two density means in the three periods are different,

where $\mu_{\Delta 1}$ $\mu_{\Delta 2}$, and $\mu_{\Delta 3}$ represent the density means for the periods P1, P2, and P3, respectively.

3.3 Reciprocity

Reciprocity refers to the extent to which relationships between actors in a social network are symmetric (Wasserman and Faust, 1994). Reciprocity arises when pairs of actors have a bidirectional response link. It can be expressed as: Reciprocity (r) = D / N, where D is the number of symmetrical (reciprocated) dyads, and N is the number of connected actors in the network.

Reciprocity means that contributors expect their information contributions will lead to their future request for information being answered by others (Kankanhalli et al., 2005). Individuals usually reciprocate the benefits they receive from others, ensuring ongoing information contribution. Reciprocity can serve as a motivational mechanism for people to contribute to information exchanging in online communities (Wang and Fesenmaier, 2003). High level of reciprocity in a network creates a general confidence that other members will respond to one’s contribution. In the online communities, reciprocity is considered a core element that completes the deliberating process because it shows that participants have taken into account the information and perspectives of each other. The two-way information from reciprocal discourses may serve to enhance further information exchanging. Prior studies indicate that information exchange in online communities is facilitated by a strong sense of reciprocity – favours given and received (Wasko and Faraj, 2005). During a disaster, people increase the demand for interaction and information exchanging. We expect that they will gain more favours from others by replying more messages. Therefore, we have the following proposition.

Proposition 4 The network reciprocity (r) will be different in the three periods.

$H_o: \mu_{r1} = \mu_{r2} = \mu_{r3}$

H_a: at least two reciprocity means in the three periods are different,

where μ_{r1} μ_{r2}, and μ_{r3} represent the reciprocity means for the periods P1, P2, and P3, respectively.

3.4 The average shortest path length and diameter

Shortest paths play an important role in the information communication within a network. The path length between two nodes of a network is defined as the number of links between them. The minimal path length is the number of links on the shortest distance between two nodes. It is useful to represent all the shortest path lengths of a network N as a matrix D in which the entry d_{ij} is the length of the geodesic from node i to node j. The maximum value of d_{ij} is called the diameter of the network and it represents the maximum shortest path length between any two nodes in a network. The average shortest path length (p) is the average of all the shortest path lengths between all pairs of nodes in a network, defined as (Watts, 1999):

$$p = \frac{1}{N(N-1)} \sum_{i,j \in N, i \neq j} d_{ij}$$

The average shortest path length is a measure of the typical separation between two nodes in a network. Shortest paths have also played an important role in the characterisation of the internal structure of a network (Wasserman and Faust, 1994). For instance, the average path length is 11 in an internet router network (Govindan and Tangmunarunkit, 2000) and 4.95 in an e-mail network (Ebel et al., 2002).

During a disaster, more individuals need to gather and request information and join in the communication network, which will increase the diameter of the network. As the network grows, the average path length will inevitably increase because more nodes are added to the network.

Therefore, we offer our final two propositions:

Proposition 5 The network diameter (d) will be different in the three periods.

$H_o: \mu_{d1} = \mu_{d2} = \mu_{d3}$

H_a: at least two diameter means in the three periods are different,

where μ_{d1} μ_{d2}, and μ_{d3} represent the diameter means for the periods P1, P2, and P3, respectively.

Proposition 6 The average shortest path length (p) will be different in the three periods.

$H_o: \mu_{p1} = \mu_{p2} = \mu_{p3}$

H_a: at least two average shortest path length means in the three periods are different,

where μ_{p1} μ_{p2}, and μ_{p3} represent the means for periods P1, P2, and P3, respectively.

4 Data

The data is from a student online forum in a university of 23,000 full-time students in Chengdu, about 50 miles from the epicentre of the Wenchuan earthquake. The city is the provincial capital of Sichuan. The earthquake had a great impact on the city. Immediately after the earthquake, the city became the base for the rescue operations.

This study focuses on an internet-based student discussion forum in the university. Online forums are widely used by college students to discuss various including topics bout campus life, social issues, history, and public news. Online forums are one of the important parts of their college life.

4.1 Data matrix

For the daily time series data, we construct social network matrices based on the interactions among participants in the forum. In electronic networks, a dyadic link is created between two individuals when one responds to another's posting (Ahuja et al., 2003). Wasko et al. (2009) define a social tie in electronic networks as the tie created between two individuals when one person responds to another's posting. As an indicator of interaction between two participants, we record instances where a participant posted a reply message on the forum. Using this information, we created an adjacency matrix for each day, in which members in the row are the ones who initiated conversations (posted seed messages), and members in the column are the ones who replied to other's messages (posted reply messages). We also measured the strength of relationship by counting number of threads participants have exchanged.

Table 1 shows a part of such a social matrix. In the matrix, each row or column represents a distinctive participant, which is identified by a unique user ID created by the forum. The values of cells indicate the degree of the interaction between each pair of participants, which is counted by the amounts of messages that participant A in the column replied to participant B in the row. For example, the value 4 in the second raw and the third column indicates that user 10,001 replied four times to user 10,002's initial posting, and the value 12 in the third raw and the second column indicates that user 10,002 replied twelve times to user 10,001's initial posting.

Table 1 An example of social matrix of the forum

	10,001	*10,002*	*10,003*	*10,004*
10,001	0	4	10	15
10,002	12	0	3	0
10,003	7	4	0	
10,004	9	7	1	0

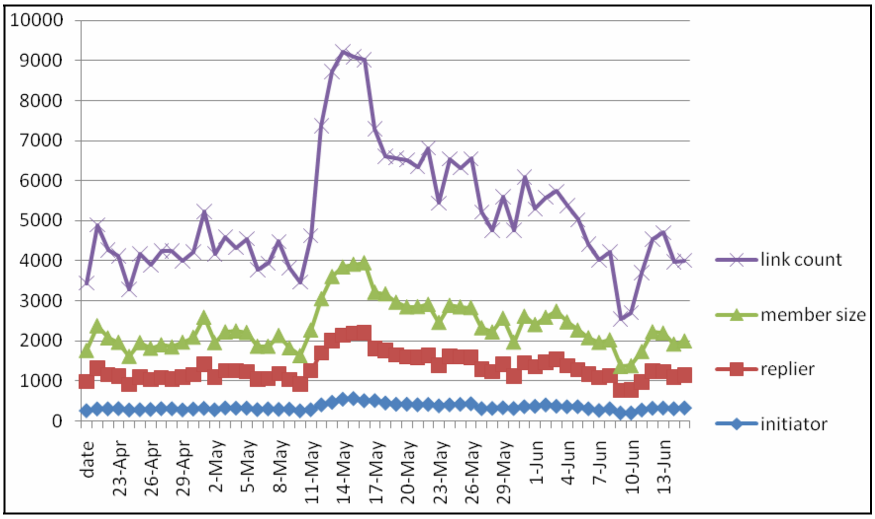
5 Network analysis results

5.1 Network growth

Network growth means networks expand by the addition of new nodes and links. We use initiators, repliers, member size, and link count to show the network growth for the online network. Initiators are those members who initially posted seed messages, and repliers are those members who replied other's previous messages. Member size is the total number of initiators and repliers excluding their overlaps. Link count is the total number of links.

Figure 1 shows all the four numbers increased shortly after the earthquake, and then after three weeks the numbers returned to the level before the earthquake. In addition, the number of links changed dramatically compared to other three measures.

Figure 1 Network growth (see online version for colours)



One-way analysis of variance (ANOVA) was used to test Proposition 1. The F-test was used to assess whether or not the means of several groups are all equal. According to Table 2, the means for the initiators in the three periods P1, P2, and P3 are 293.10, 409.95, and 304.48, respectively. There is a significant mean difference between the initiator numbers in the three periods ($F(2, 60) = 28.586$, $p < .05$). These results show the means of the initiator numbers are different in the three periods and the initiators increased greatly in P2 (the earthquake period).

To test which period is responsible for the difference, a post-hoc test was used. The results show that the mean of the initiators in P2 is significantly different from the means in the P1 and P3. There is no significant difference between the means of P1 and P3.

The replier number increased significantly in P2 as well. According to Table 2, the means for the repliers in the three periods P1, P2, and P3 are 826.19, 1,222.05, and 897.00, respectively. There is a significant difference between the replier numbers in the three periods ($F(2, 60) = 34.468$, $p < .05$). The post-hoc test shows that the mean of the initiators in P2 is significantly different from the means in the P1 and P3 and no significant difference between the means of P1 and P3.

The member size is the total number of initiators and repliers. It also increased significantly in P2. The means for the member sizes in the three periods are 877.62, 1,287.05, and 897.00, respectively. The difference between the member sizes in the three periods is significant ($F(2, 60) = 34.468$, $p < .05$). The post-hoc test shows that the mean of the initiators in P2 is significantly different from the means in the P1 and P3 and no significant difference between the means of P1 and P3.

Table 2 ANOVA results

		Initiators	*Repliers*	*Member size*	*Links*	*Density*	*Reciprocity*	*Diameter*	*Average shortest path length*
Mean	P1	*293.10*	826.19	877.62	2,154.81	.002871	.098576	877.62	4.08
	P2	*409.95*	1,222.05	1,287.05	3,723.24	.002314	.068076	1,287.05	4.20
	P3	*304.48*	844.71	897.00	2,217.81	.002795	.073824	897.00	4.30
F value		28.586	33.895	34.468	46.091	9.244	14.925	34.468	3.180
p value		.000	.000	.000	.000	.000	.000	.000	.049
Post-hoc test (*p* value)	P1 vs. P3	.783	.938	.935	.938	.851	.000	.935	.038
	P2 vs. P1	.000	.000	.000	.000	.001	.000	.000	.381
	P2 vs. P3	.000	.000	.000	.000	.003	.599	.000	.467

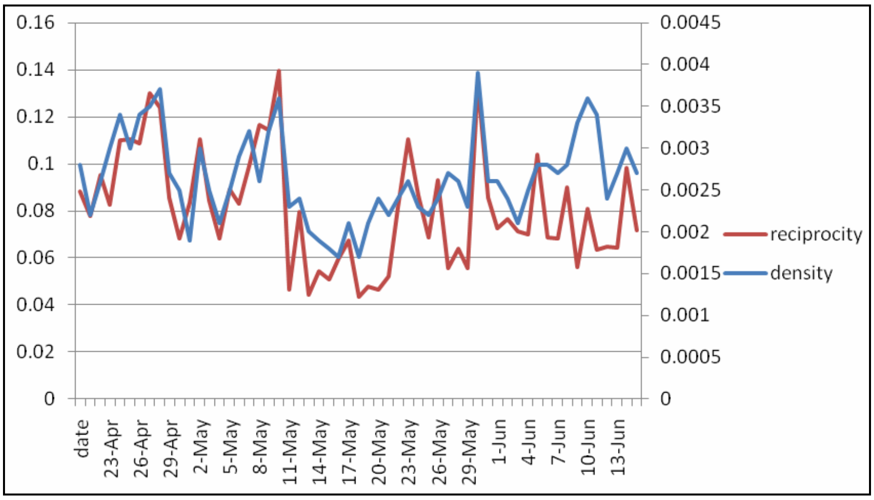
Notes: *F* value is the test statistics for testing model significance; *p*-value is used to determine if the test statistics is significant;
Post-hoc test is for testing the significant differences between all pairwise comparisons.

The links show the similar pattern to the nodes. The means for the links in the three periods are 2,154.81 for P1, 3,723.24 for P2, and 2,217.81 for P3. There is a significant difference between the link numbers in the three periods (F (2, 60) = 46.091, p < .05). The post-hoc test shows that the mean of the link in P2 is significantly different from the means in the P1 and P3 and the difference between the means of P1 and P3 is insignificant.

5.2 Network density and reciprocity

Figure 2 shows that both the density and the reciprocity dropped shortly during the earthquake, and then three weeks after the quake the density returned to the level before the earthquake while the reciprocity did not.

Figure 2 Network density and reciprocity (see online version for colours)



The ANOVA results show that the network density decreased significantly in P2. Table 2 shows that the means for the density in the three periods P1, P2, and P3 are .002871, .002314, and .002795, respectively. The difference between the densities in the three periods is significant with F (2, 60) = 9.244 and p < .05. The post-hoc test shows that the mean of the density in P2 is significantly different from that in P1 or P3. No significant difference is found between the means of P1 and P3.

The network reciprocity decreased significantly in P2 and P3. The means for the reciprocity in the three periods are .098576 for P1, .068076 for P2, and .073824 for P3. Significant difference is found among the reciprocities in the three periods (F (2, 60) = 14.925, p < .05). The post-hoc test shows that the mean of the reciprocity in P1 is significantly different from the means in the P2 and P3. There is no significant difference between the means of P2 and P3.

Both the network density and reciprocity decreased despite the great increase of members who joined in the forum during the earthquake period. However, the reciprocity of P3 did not return to the level in P1. Reciprocity is a dyadic message exchange between members, where the motivation to help others stems from the expectation of obligation and reciprocity from the receiver. After the earthquake, many new members entered the online forum and they were not familiar with existing members. It takes time to establish reciprocity between new and existing members. This may explain why the reciprocity decreased in P2.

Wasko et al. (2009) explained that in an electronic network individuals must have both the ability and willingness to post an answer in order to reply other's messages. In addition, in an open, fluid electronic network, individuals participating are typically strangers, making it difficult to create and enforce social sanctions for non-reciprocation.

5.3 Average shortest path length and diameter

Figure 3 the diameter *D* increased greatly shortly after the earthquake, but two weeks after the event it returned to the level before the earthquake. This result confirms the Proposition 5. The diameter increased because the more individuals join in the electronic network to exchange information during the earthquake period. Right after the earthquake, people needed to gain knowledge about what happened and express their emotions.

Figure 3 Average shortest path length and diameter (see online version for colours)

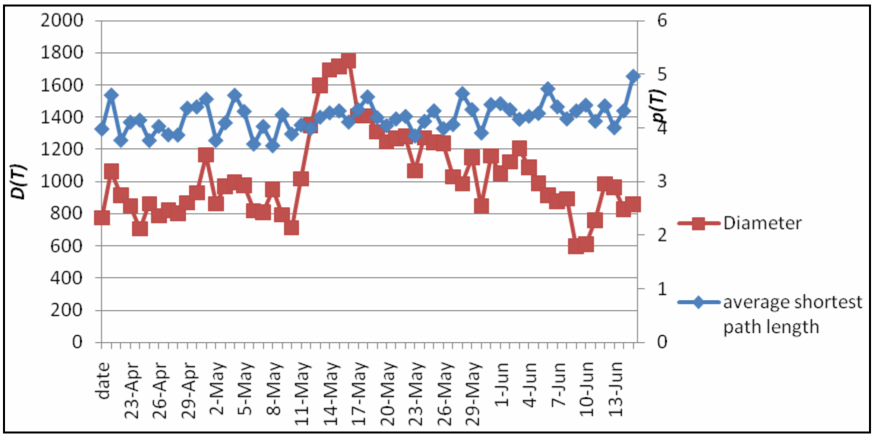


Table 2 shows that the network diameter increased significantly in P2, and the means for the diameter in the three periods are 877.62, 1,287.05, and 897.00, respectively. The difference in the three periods are significant (F (2, 60) = 34.468, $p < .05$). The post-hoc test shows that the mean of the diameter in P2 is significantly different from that in the P1 or P3. No significant difference is found between the means of P1 vs. P3.

The average shortest path length increased in P2 and P3. Table 2 shows that the means for the average shortest path length in the three periods P1, P2, and P3 are 4.08, 4.20, and 4.30, respectively. They are significantly difference from each other (F (2, 60) = 3.18, $p < .05$). The post-hoc test shows that the mean in P3 is significantly different from the means in the P1, but no significant differences are found between the means of P2 vs. P1, or P2 vs. P3.

6 Discussion and conclusions

6.1 Summary

This study empirically examines the dynamics and changes of network communication structure of an online discussion forum during a natural disaster. The open, fluid electronic network allows members easily to join and participate in the forum communication. The communication links and the numbers of initiators and repliers increased during the earthquake. We also found that with the network growth, network density and reciprocity decreased, while the average shortest path length increased.

Our study makes two primary contributions. This research is significant because it examines the individual network communication dynamics that appeared in a short time after a natural disaster. Few previous studies have examined this type of communication network changes that are related to natural disaster.

This research also provides a framework for studying dynamics and changes of electronic networks, from network topologies, hypothesis definition, and data extraction, and data analysis. This research method can be extended for future studies on the properties and structure of networks over time.

6.2 Limitations

Our research has some limitations. First, this study examined only one specific type of electronic network, an online discussion forum during the earthquake. People used other features of World Wide Web for communication during the earthquake, such as electronic mails, listservs, chatrooms, and social network websites. By taking these forms of communication into consideration opens new opportunities for the investigation of how people use different media to share information, connect family and friends, and form networks during a major disaster.

In addition, the online discussion forum in the study was from only one organisation and only the members in the organisation could participate in the discussion. As a result, cautions must be exercised when generalising the findings. Future research could extend these results to different types of discussion forums that may show different member behaviours. For example, open public discussion forums may show different interactions and network structures, with different implications for their outcomes.

Finally, other events, natural disasters or not, can certainly cause the same dynamics in the social networks identified in this study. This suggests two avenues for future studies. First, effect of natural disasters on the social network must be isolated to avoid the compounding causes from other type of events. Second, different types of natural disasters can be compared to examine whether they cause the different dynamics and patterns in the social networks.

6.3 Practical implications

This study has practical implications in the following aspects. First, emergency management requires multiple channels for communication and coordination. Electronic social networks can play an important and significant role in distributing information, coordinating community activities, and offering person-to-person help during a disaster emergency. Many electronic networks are open networks, which make them very attractive for individuals to seek information and ask for assistance. Electronic networks have unique functions to distribute information and link individuals together. Therefore, it is important to understand communication patterns and structures of electronic networks during a disaster.

Strategies need to be developed to attract more responses, increase the reciprocity, and sustain the connections after a disaster. Moderators can play a proactive role in these aspects. Previous literature has argued that moderators can serve to enhance participation in online discussion forums (Edwards, 2002). In particular, moderators can help to identify new members and encourage them to respond to postings of others. Moderators can archive valuable messages and post them on noticeable places in the forums. As a caveat, the moderators should assume the role of facilitators and avoid inducing an impression that they are authoritative figures.

In additional, sophisticated software can be integrated into electronic social networks. Network scanning tools may be developed to monitor network structure formation and development in real time. Interactions among participants could be automatically captured with facilities of buttons for replying and quoting a message. Such information may allow forum managers to devise appropriate interventions to encourage the formation of desirable network structures. This will improve the likelihood of generating more reply and reciprocity and enrich content and interactions in the discussion forum.

References

Ahuja, M.K., Galletta, D.F. and Carley, K.M. (2003) 'Individual centrality and performance in virtual R&D groups: an empirical study', *Management Science*, Vol. 49, No. 1, p.21.

Barabâsi, A-L. and Albert, R. (1999) 'Emergence of scaling in random networks', *Science*, Vol. 286, pp.509–512.

Blau, P.M. (1997) *Inequality and Heterogeneity*, Free Press, New York.

Danowski, J.A. and Edison-Swift, P. (1985) 'Crisis effects on intraorganizational computer-based communication', *Communication Research*, Vol. 12, No. 2, pp.251–270.

Ebel, H., Mielsch, L-I. and Bornholdt, S. (2002) 'Scale-free topology of e-mail networks', *Physical Review*, Vol. 66, p.035103.

Govindan, R. and Tangmunarunkit, H. (2000) 'Heuristics for internet map discovery', in *Proceedings of IEEE INFOCOM 2000*, v3, p.1371, Tel Aviv, Israel.

Emirbayer, M. (1997) 'Manifesto for a relational sociology', *American Journal of Sociology*, Vol. 103, No. 2, pp.281–317.

Kankanhalli, A., Tan, B.C.Y. and Wei, K.K. (2005) 'Contributing knowledge to electronic knowledge repositories: an empirical investigation', *MIS Quarterly*, Vol. 29, No. 1, pp.113–143.

Kapucu, N. (2006) 'Interagency communication networks during emergencies: boundary spanners in multiagency coordination', *American Review of Public Administration*, Vol. 36, No. 2, pp.207–225.

Lu, Y. and Yang, D. (2011) 'Information exchange in virtual communities under extreme disaster conditions', *Decision Support Systems*, Vol. 50, No. 2, pp.529–538.

Mitchell, J.C. (1969) 'The concept and use of social networks', in Mitchell, J.C. (Ed.): *Social Networks in Urban Situation*, Manchester University Press, Manchester.

Monge, P.R. and Contractor, N. (2003) 'Using multi-theoretical multi-level (MTML) models to study adversarial networks', in Breiger, R.L., Carley, K.M., Pattison, P. (Eds.): *Dynamic Social Network Modeling and Analysis, Proc. Dynamic Social Network Modeling and Analysis Workshop*, U.S. National Research Council, Committee on Human Factors, pp.325–344.

Palen, L., Hiltz, S.R. and Liu, S.B. (2007) 'Online forums supporting grassroots participation in emergency preparedness and response', *Communications of ACM*, Vol. 50, No. 3, pp.54–58.

Perry, R.W. and Mushkatel, A.H. (1984) *Disaster Management: Warning Response and Community Relocation*, Quorum Books, Westport, CT.

Rogers, E.M. and Sood, R. (1981) *Mass Media Operations in a Quick-Onset Natural Disaster: Hurricane David in Dominica*, University of Colorado, Colorado, USA.

Wang, Y. and Fesenmaier, D.R. (2003) 'Assessing motivation of contribution in online communities: an empirical investigation of an online travel community', *Electronic Markets*, Vol. 13, No. 1, pp.33–45.

Wasko, M.M. and Faraj, S. (2005) 'Why should I share: examining social capital and knowledge contribution in electronic networks of practice', *MIS Quarterly*, Vol. 29, No. 1, pp.35–57.

Wasko, M.M., Teigland, R. and Faraj, S. (2009) 'The provision of online public goods: examining social structure in an electronic network of practice', *Decision Support Systems*, Vol. 47, No. 3, pp.254–265.

Wasserman, S. and Faust, K. (1994) *Social Network Analysis: Methods and Applications*, Cambridge University Press, Cambridge.

Watts, D.J. (199) *Small Worlds: The Dynamics of Networks Between Order and Randomness*, Princeton University Press, Princeton, New Jersey.

Watts, D.J. and Strogatz, S.H. (1998) 'Collective dynamics of 'small-world' networks', *Nature*, Vol. 393, No. 6684, pp.440–442.

Weick, K.E., Sutcliffe, K.M. and Obstfeld, D. (1999) 'Organizing for high reliability: processes of collective mindfulness', in Cumings, B.M. (Ed.): *Research in Organizational Behavior*, Vol. 21, pp.81–123, JAI Press, Greenwich, C.T.