USE OF CROWD-SOURCED PHOTOGRAPHS IN POST-DISASTER DAMAGE ASSESSMENT

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Abstract: This paper discusses the use of crowdsourced photographs after an earthquake to improve rapid damage assessments. Following the 2011 Christchurch earthquake, remote analysts were involved in the Global Earth Observation Catastrophe Assessment Network (GEOCAN), a crowd-sourcing technology that allows remote analysts to identify building damage using aerial imagery. In this paper, attention is focused on what inventory and damage capture standards would be required for crowd-sourced photographs to improve the accuracy of damage assessments. Results from a survey of social media users identifies whether the public would be willing to follow these guidelines. Potential strategies are recommended to improve future remote aerial based mapping techniques using crowd-sourced photographs. Barriers preventing its implementation are identified.

Introduction

On the 22nd February 2011, a Mw 6.3 earthquake struck Christchurch, New Zealand. The Global Earth Observation Catastrophe Assessment Network (GEOCAN), a remote sensing crowd-sourcing platform was used to assess building damage from aerial imagery. This paper focuses on the potential use of crowd-sourced photographs following an earthquake as a supplement to current remote aerial mapping techniques, such as GEOCAN, to improve the rapid analysis of damage. A survey circulated to social media users who uploaded photographs following the Christchurch earthquake identifies social media user's motivation for uploading photographs and whether they would be willing to follow guidelines which make the photographs beneficial for remote analysts. This paper assesses if it is feasible to crowd-source images post-disaster and how this strategy could be implemented and improve current remote aerial based mapping techniques.

Crowdsourcing refers to the collection of data from crowds of people. Examples include: Wikipedia, an online encyclopaedia where information is submitted from members of the public; and Amazon Mechanical Turk, a web-based market place which advertises human intelligence tasks to complete for a small fee. After a disaster, resources often become stretched. Rather than relying on a few individuals, utilising crowdsourcing and citizen journalism can help to raise situational awareness and provide valuable data (Goodchild and Glennon, 2010). The Ushahidi platform is an open-source crisis mapping software. It was initially used after protests in Kenya, but since then was used after both the Haiti, 2010 and Christchurch, 2011 earthquakes. Ushahidi obtains information from social media websites and maps it. The online recovery maps produced following the Christchurch earthquake obtained over 100,000 visits and were used to provide useful geographic information e.g. where to find food (McNamara, 2011; Ushahidi, 2011). A reduction in the time taken to collect and analyse data has the potential to result in a faster deployment of Search and Rescue teams; rapid assessment of damage and increased efficiency of response coordination (Barrington et al., 2011). Limitations and concerns related to the crowdsourcing of data and/or use of social media include internet access and malicious content. A recent study (Sutton, 2012) identified problems with access to the internet following the Christchurch earthquake and argued that those who did not have the means of access to the internet may be forgotten about when using crowdsourcing platforms to co-ordinate response strategies. A number of major network providers, including Vodafone advised "*customers use calls only for emergencies and limit*

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mobile data usage (such as Facebook, Twitter and video or picture messaging) to avoid strain on the network" (The National Buisness Review Staff, 2011; Pullar-Strecker, 2011).

GEOCAN is a crowd-sourcing technology that allows remote analysts to identify building damage using aerial imagery. After an earthquake, polygons are drawn around individual buildings if they are collapsed or heavily damaged, using aerial imagery as a guide. The buildings are then tagged with damage grade classifications. Greene et al. (2011) describes the technology in more detail. GEOCAN was inspired by the development of the online Virtual Disaster Viewer after the 2008 Wenchuan, China, earthquake. Two weeks after the Haiti earthquake, GEOCAN was launched and an initial analysis was completed within 96 hours by volunteers. Following the Christchurch earthquake it took several months to launch GEOCAN with an improved interface: TOMNOD. However, more urgency is intended for future events and the platform could be used for a rapid analysis, similar to the Haiti investigation (Greene et al. 2011). Research of Christchurch's GEOCAN results (Foulser-Piggott et al., 2014) indicates the GEOCAN analysis did not identify 64% of badly damaged buildings (red or yellow) in the study area (64% omission error). The study presented different factors that contributed to the accuracy of GEOCAN analyses including: analyst experience; type of imagery and building typology. The higher resolution of the aerial imagery makes building delineation and damage assignments easier. The study found that different structural typologies had different omission errors: unreinforced masonry (56%); reinforced concrete and steel (74%) and timber (82%). Reinforced concrete buildings were more likely to have internal damage and timber buildings were more likely to have damage to their foundations which is difficult to identify from aerial imagery. The study recommends improvements for future applications including: better quality and resolution of imagery; good quality pre-event imagery; building footprints pre-defined; assign a no visible damage grade; take into account user experience when assigning areas to analyse; provision of training; standardise damage grade for field missions and remote-sensing; and use of sample field studies as validation exercises.

Spence and Saito (2010) compared damage assessments following the Haiti earthquake from three datasets: high-resolution satellite images (GEOCAN), Pictometry (aerial oblique imagery) and ground surveys. The results showed Pictometry was recognising a slightly larger proportion of buildings with a damage level of D4 or D5, using the EMS-98 damage assessment (Grünthal, 1998) compared to GEOCAN. Unidentified GEOCAN damage included pancake and soft story collapse as this was not visible from straight-down aerial imagery. However, in comparison to ground-observations, Pictometry still had its limitations. Only 63% of buildings classified as D4 and D5 on the ground were identified by the oblique images.

The accuracy of remote aerial based mapping techniques could be improved if remote analysts view photographs of the building alongside the aerial imagery. Currently, photographs are collected from field missions and subsequently archived. The photographs can then be used as examples of different types of damage or evidence of damage in different locations. A website designed by Cambridge Architectural Research Ltd. called EEPI (Earthquake Engineering Photographic Investigation) Map, investigated the feasibility of assigning damage levels and structure types to buildings through photographs. Problems with cataloguing photographs were identified and included: photographs were only of one elevation; lack of detailed photographs; identifying the location; quality of the photograph; and a lack of scale (Foulser-Piggott et al., 2013). Figure 1 shows two images of the same building but of different elevations. The damage level of the building appears to be lower when viewing the front elevation in comparison to viewing the side. Overcoming these barriers helps to formulate data capture standards which would help photographs be useful for rapid analysis.

Figure 1: Front (left) and side (right) elevation of a damaged building, Bam, Iran, 2003. Source: EERI.

A simulation at Disaster City (Kiltz and Smith, 2011), a training facility in Texas, investigated the potential of collecting images immediately after an earthquake by using a team of volunteers. Pairs of volunteers were responsible for taking photographs and manually recording the location of different areas within a city. These images were then sent via the internet to a remote Geographic Information Systems (GIS) technician who was responsible for mapping the images either using metadata or information provided in the emails. Due to inaccuracies in global positioning systems (GPS), it was easier for the technician to manually map the photographs. The photographs could then be used for damage assessments by a City Engineer. Although the simulation was a success, barriers which need to be addressed are: upload time of photographs; inconsistencies in photographic content and determining location. Other research has shown how photographs can be used to track recovery rather than to make a rapid assessment. Following hurricane Katrina, repeat photography was used to monitor the recovery of individual buildings. Each photograph was given a recovery score and was geo-located (Burton et al, 2011). This allowed recovery rates to be monitored and combined with other GIS data available e.g. socio-economic status of the area.

Data collection and analysis

Following the literature review, a set of guidelines was identified – displayed in table 1. Two surveys were then created using the guidelines and other information obtained from the literature review.

Table 1: Guidelines created following literature review.

Guideline identification letter	Guideline
A	Take photographs of multiple elevations/sides of the same building
B	Take pictures of undamaged buildings
C	Set the GPS on camera
D	Manually record the location of the photograph and add these details when uploading photographs
E	Take close-up photographs of a building
F	Add a sense of scale in photographs e.g. a pen
G	Record on a hand-drawn plan of the area, where detailed photographs are taken from and upload this plan with the photographs
H	Take internal photographs
I	Take photographs of the same building over a number of days
J	Use step by step guidance through an app to take photographs

The first survey: ‘Social Media and Post-Earthquake Photographs’ was circulated to potential respondents via social media. For example, on Twitter, individuals who uploaded photographs following the earthquake were contacted directly and the survey was circulated using the hashtag #eqnz and by tagging organisations such as @ChChEarthquake to increase visibility.

Other sites used included: Facebook, Flickr, Tumblr and Instagram. Questions identified why respondents used particular social media websites, how and when they took/uploaded photographs and whether they would be willing to follow the photographic guidelines. As part of the survey, respondents were asked to leave their email to obtain additional information. In total, 71 responses were received. The second survey, 'GEOCAN – Use of crowd-sourced photographs to assist in categorisation of building damage post-disaster' was circulated to people identified in the literature review as being involved in either/both the Haiti and/or Christchurch GEOCAN investigations. Although only 4 responses were received, email correspondence/interviews provided further information.

Social Media

The following section provides an overview of the social media survey results. For a full breakdown of questions and answers, refer to the following report: Baker (2015). Overall, 91% of the respondents uploaded photographs following the Christchurch earthquake. The respondents used a range of social media websites but Facebook was clearly the most popular from the sample as 79%[3] of respondents used it. This was followed by Flickr (48%), then Twitter (17%). This may not be representative of which websites were used following the earthquake due to the limited sample size, however it is useful to know if different website users had different viewpoints. Respondents used particular websites for the following reasons: the website features; their family and friends use that particular website; they already had an established profile; and for its public sharing ability. Facebook was more popular for its sharing ability with friends and family, whereas Flickr was popular due to its photographic capabilities e.g. setting licensing on photographs. Twitter was popular for sharing information with large numbers of people. When asked if respondents would be willing to use a disaster specific website, 43% said yes, 39% said they would prefer to use existing social media websites but allow their photographs to be used, 15% were not sure and only 4% said no. These results indicate the majority of the respondents would be willing for their photographs to be utilised for rapid damage assessments. A high proportion of people would prefer using existing sites because of time constraints and existing profiles.

The number of photographs uploaded by the respondents following the event varied significantly – see table 2. If 10% of people upload more than 1000 photographs each, methods for filtering and limiting the number of photographs need to be addressed in the overall crowd-sourcing strategy. The majority of the respondents uploaded their photographs for: archive purposes (26%); letting family members/friends know they were OK (25%) and news reporting (19%). Although their primary purpose was not to help with rapid damage assessments, this could be a secondary benefit of photographs which are being uploaded to social media anyway.

Table 2: Number of photographs uploaded to social media by respondents

Number of photographs uploaded	1-20	21-50	51-100	101-1000	1000+
Percentage of respondents (%)	26%	20%	16%	26%	11%

The majority (86%) of the respondents were permanent residents in Christchurch when they took the photographs. The point at which permanent residents took their photographs was evenly spread between: the same day as the earthquake; 1-2 days after the earthquake; within a week; 1-2 weeks; 3-4 weeks; a month to a year; and over a year after the earthquake. When compared to the time the photographs were uploaded, there is clearly a delay uploading photographs in the first few days – see Figure 2. The survey results show that 7% of respondents uploaded photographs on the same day as the earthquake and 12% uploaded photographs 1 to 2 days after. This is the timeframe which would be useful for rapid analysis providing remote aerial based mapping techniques were launched straight away.

[3] Respondents could select more than one website.

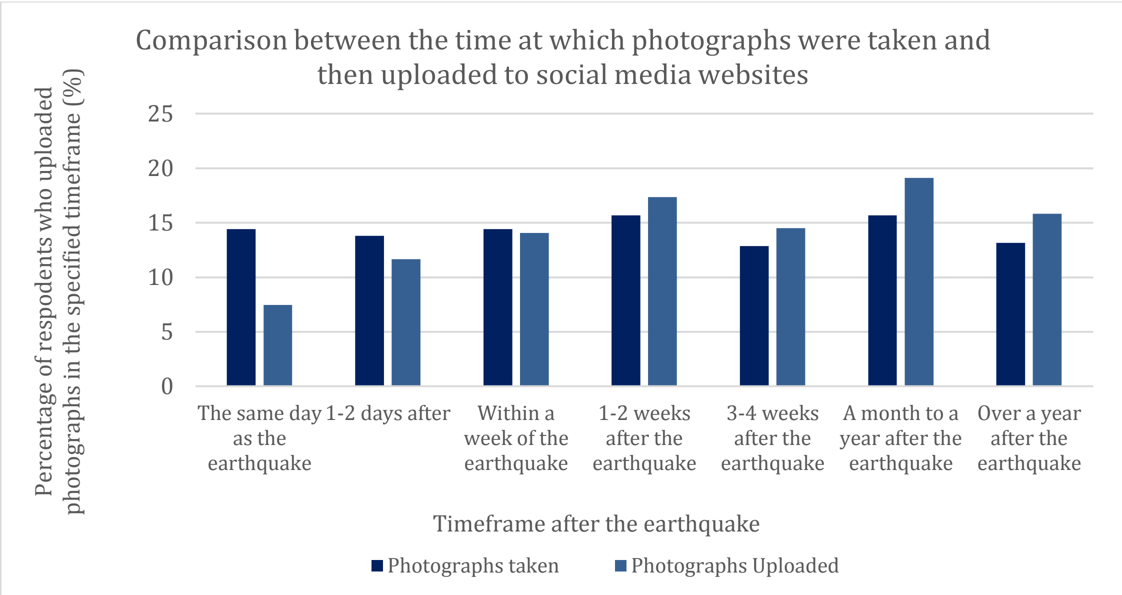


Figure 2: Comparison between the time at which the photographs were taken and then uploaded to social media websites

Within the survey, the respondents were asked how long they suffered from internet problems as this is a potential barrier to the implementation of crowdsourcing photographs - 59% of respondents had problems with their internet by various amounts. Figure 3 indicates over 50% of respondents who had problems with their home internet connection had issues for over 7 days. The majority (86%) of respondents uploaded their photographs via a laptop at their home using an Ethernet cable or WiFi, this could explain why there was a delay between taking the photographs and uploading them. Other factors to be considered for the delay include: time taken to organise photographs; access to a computer and that the photographer would have had other priorities immediately after the earthquake.

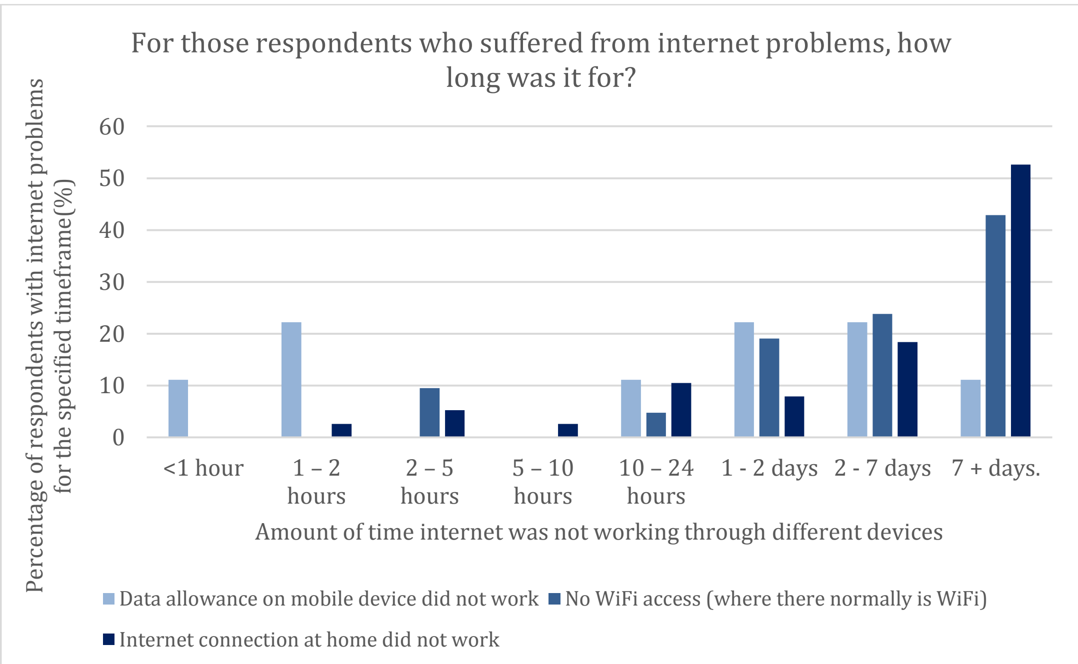


Figure 3: For those respondents who suffered from internet problems, how long was it for?

The majority of the respondents either used[4] a mobile phone (35%), digital camera (35%) and/or a high quality camera e.g. SLR (28%) to take their photographs. The number of Twitter users using a mobile phone (50%) and the number of Flickr users (40%) using an SLR was greater than the overall average. Twitter users used the website for news reporting and the quality of the image may not matter as much, whereas Flickr users may be more interested in the final photograph's composition/quality. In terms of GPS availability on devices, 13% of respondents were not sure if they had it; 41% did not have GPS and 46% did. From those which did have GPS, only 34% used it all the time and 38% never used it, others used GPS by varying amounts. Reasons for not using the GPS function included: to conserve battery life and the respondent not wanting people to know their personal location. Although GPS is important for geo-locating photographs, a recent study (Kiltz and Smith, 2011) showed that it is sometimes easier for a remote GIS technician to use a street address due to inaccuracies and inconsistencies between GPS devices.

Respondents were asked to say whether they were very likely, somewhat likely, neutral, somewhat unlikely or very unlikely to follow the recommended set of guidelines. Figure 4 groups the results for very and somewhat likely or unlikely. The results indicate that the majority of respondents would be willing to follow the proposed guidelines, in particular: taking close-up photographs of a building; taking photographs of multiple elevations; adding a sense of scale; and manually recording the location and entering the details when uploading the photographs. There was only one guideline that respondents were less likely to follow: recording on a hand-drawn plan where detailed photographs were taken. This is probably due to the time-consuming nature of the task and having the confidence to draw a plan and accurately locate the photograph. Opinion regarding the use of an app which provides step by step instructions was divided. Those who did not want to use it are likely to feel restrained creatively. Although 10-30% of respondents were opposed to the guidelines, the photographs from those who were not opposed, could be utilised. A specific hashtag such as #eqguidelines could be used to show guidelines have been followed. Feedback was received from over 50% of the respondents regarding the guidelines and the comments were categorised, these included: positive comments providing the guidelines were beneficial; concern over safety; concern the guidelines were anti-creative; questions on how to incentivise people; and stating that people had other priorities. Concern over safety and the fact people will have other priorities need to be addressed in the final recommendations. Although people were concerned about anti-creativity, it needs to be accepted that the guidelines cannot be embraced by everyone. However, it is important to analyse how to implement the guidelines. Email correspondence suggested incentivising/informing people by: using volunteers; emphasising the benefit for insurance purposes; establishing a well-known presence on social media pre-event; and getting guidelines to 'go viral'.

[4] Could select more than one device.

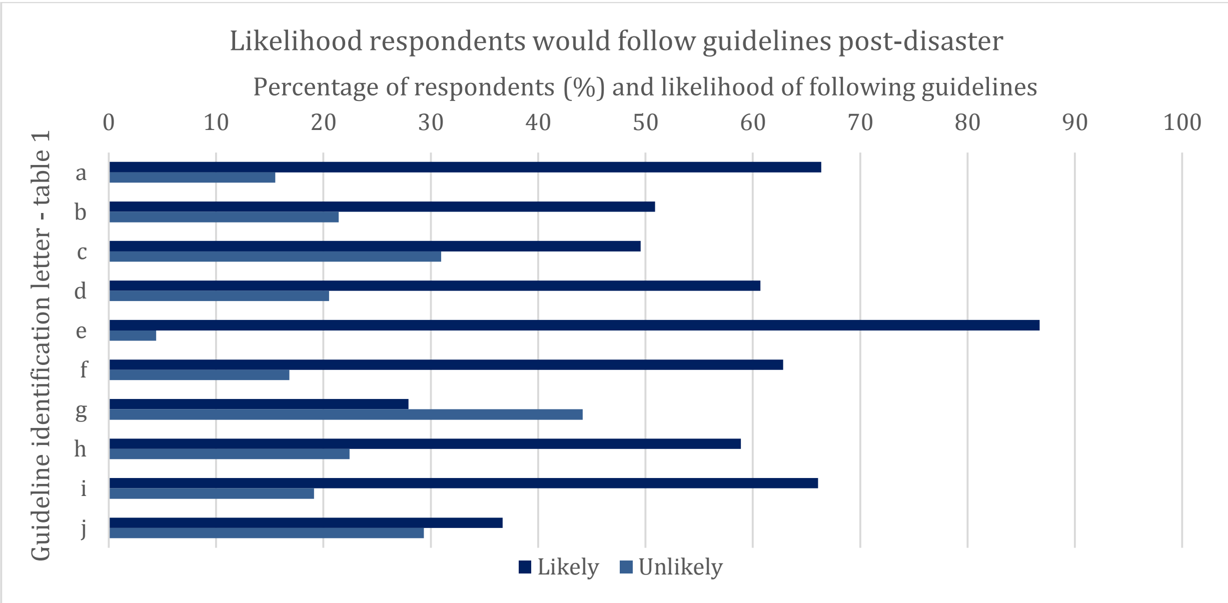


Figure 4: Likelihood respondents would follow guidelines post-disaster – see table 1 for guideline descriptions

<u>GEOCAN</u>

Although the responses were limited, an analysis of the GEOCAN survey results was undertaken to see if there was consensus. All of the guidelines (which are the same as the ones proposed for the social media survey) put forward to the former GEOCAN analysts were seen as beneficial. One respondent emphasised the importance of understanding the whole building and not just having close up detailed shots. The main benefits seen by the respondents for the guidelines and crowd-sourced photographs were for comparison purposes and the provision of additional detail. Although there was a difference in opinion regarding what former problems identified in GEOCAN investigations could be overcome by photographs, all respondents agreed they would be useful for identifying soft storey collapse.

Respondents were asked to rank benefits and limitations associated with crowdsourced photography which had been identified in the literature. Some of the respondents stated they did not feel it was appropriate to rank these due to a lack of experience and that some were perceived as equal value to others. Overall, the results show that targeting help in a disaster was ranked the highest in terms of importance. Other options included: archive of images; education purposes for future GEOCAN analysis; general education of engineers and architects; insurance purposes; and journalistic purposes. During email correspondence, two issues which arose regarding GEOCAN were: for the analysis of damage patterns, undamaged buildings should be included; and, disappointment with the GEOCAN results due to the unpreparedness of launching the software.

Recommendations and Implementation

The survey of social media users indicated the majority of respondents would be willing to follow guidelines. Taking acceptability and personal safety into account, guidelines G, H and J (see table 1) were dismissed. Therefore, the following data capture standards are suggested:

1) Take photographs of multiple elevations of the same buildings.
2) Manually record the location of photographs and add these details when uploading photographs.
3) Take close-up photographs of a building*.
4) Add a sense of scale in photographs e.g. a pen*.
5) Set GPS on camera.
6) Take pictures of undamaged buildings.

* Do not put personal safety at risk

Guidelines 1 and 2 are very important for the rapid analysis of damage. Guidelines 3 and 4 are useful for providing extra detail but not essential if the photographer were to put themselves in danger. Guideline 5 is not essential providing guideline 2 is followed, however, it is useful for validation purposes. Although guideline 6 will not identify damaged areas, it is useful to record to avoid data gaps and allow for consistency. For recovery purposes people should be encouraged to:

7) Take photographs of the same building over a number of months provided it is not in an area zoned off from entering.

To implement this type of investigation, there needs to be participation by four teams/groups of people:

- Pre-event crowdsourcing and emergency preparedness team.
- People collecting and uploading photographs post-earthquake.
- GIS technicians ensuring photographs are correctly geo-located and validated.
- Remote analysts of aerial imagery and photographs.

1) Pre-event crowdsourcing and emergency preparedness team:

As described in the Introduction, for a GEOCAN-type analysis to take place, pre-event, and post-event imagery is required as well as building outlines. Pre-event imagery could be obtained by encouraging the public through insurance requirements; officials as part of the emergency preparedness plan; or the utilisation of technology such as Google Street View.

A key piece of information required for the post-disaster damage assessment, which was missing from the GEOCAN project was delineated buildings in the affected area. This procedure could be crowdsourced using websites such as Amazon Mechanical Turk. Individuals would be paid a small fee e.g. 1p for completing a geographic area. This could also occur after the earthquake.

As shown by the survey results, the public will have other concerns following a disaster and unless they are aware of this scheme and its benefits to provide targeted help and rapid damage assessment, they are unlikely to take part. A website or social media website page needs to obtain a presence pre-event and publish guidelines, training videos and examples. This can also be used to incentivise the public to collect pre-event imagery.

2) People collecting and uploading photographs post-earthquake:

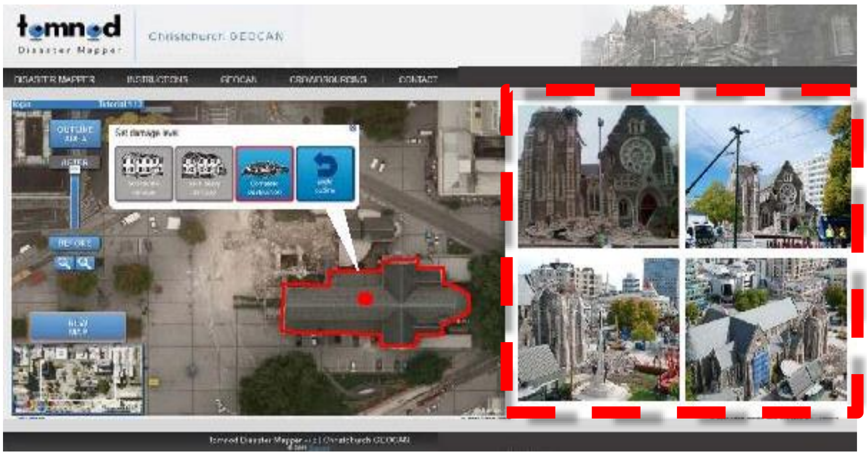
As previously described, crowdsourced images from existing social media websites with a specific hashtag e.g. #eqguidelines can be collected post-earthquake. However, barriers to this include having too many photographs and problems with the internet/congestion on phone lines. An app/website could be used to indicate where photographs had already been taken or people could select/tweet where they are going to go using a different hashtag e.g. #eqcrowdsource. Once photographs have been collected of a location, they would need to be validated by a GIS technician and filtered to remove multiple co-located images.

3) GIS technicians ensuring photographs are correctly geo-located:

The GIS technicians, similar to the Disaster City scenario (Kiltz and Smith, 2011) are responsible for organising the crowdsourced photographs and assigning them to the correct location/building polygon. This will require some manual interpretation as the location of the photograph (using GPS) is not the same as the location of the building. As discussed, this process would be easier if the building polygons and pre-event imagery already existed.

4) Remote analysts of aerial imagery and photographs:

A remote aerial based mapping analyst conducting a damage assessment will be able to see photographs alongside aerial imagery. Figure 5 displays a suggested adaptation to the current GEOCAN interface, which can be applied to other aerial based mapping interfaces. If a building has already been documented without a photograph, the analyst will be informed a photograph has appeared and use it to validate their previous classification.



Proposed adaptations:
- Pre-defined building polygons.
- Photographs appear alongside aerial imagery.

Figure 5: Suggested improvements to TOMNOD/GEOCAN interface - crowdsourced photographs of damage (location validated by GIS technician) appear alongside aerial imagery (see right-hand side). Original TOMNOD image source: Foulser-Piggot et al (2015). Photographs source: Flickr

These recommendations can be considered as an extension to the current remote aerial based mapping techniques by using an existing resource, i.e. crowdsourced photographs. In order to implement these ideas and to understand if they overcome some of the problems outlined in Foulser-Piggott et al. (2015) further research should be conducted. This includes tests by remote sensing analysts to see if photographs improve the accuracy of their classification and investigations into the capability of phone/internet networks and how these problems could be overcome. The collection of crowd-sourced images after the initial analysis can provide alternative benefits including: validation of results which did not include photographs; education purposes; and training.

Conclusion

The social media survey results indicated that the majority of respondents would be willing to follow most of the proposed guidelines, which had been established from the literature review and previous critiques of remote aerial based mapping techniques. The final data capture standards include: taking photographs of multiple elevations; manually recording the location of photographs and entering the details when uploading photographs; taking close-up photographs; adding a sense of scale; setting the GPS on the camera; and taking pictures of undamaged buildings. Taking pictures of the same building over a number of months is useful for recovery purposes. Although the guidelines were acceptable to those surveyed, a potential barrier to the implementation of crowdsourced photographs is internet access following an earthquake. Survey results showed a delay between uploading and taking photographs and that some respondents did not have access to the internet from their home for over a week. It is important to avoid congestion on the phone lines which may be exacerbated by uploading large numbers of photographs. This needs to be researched further before people are encouraged to upload photographs post-event.

If internet problems are overcome, the crowdsourcing strategy should be implemented through four groups of people: pre-event crowdsourcing and emergency preparedness teams; people collecting and uploading the photographs post-event; GIS technicians; and remote analysts. This paper proposes that members of the public would submit photographs to social media using a hashtag e.g. #eqguidelines and stating the location in a caption. The photographs are then mapped by remote GIS technicians. Proposed changes to remote aerial based mapping interfaces would allow remote analysts to view the validated photographs alongside aerial imagery to improve the accuracy of their damage assessment.

Acknowledgements
This research was conducted following a research grant from the Earthquake Engineering Field Investigation Team (EEFIT). The authors would like to thank Robin Spence, Cambridge Architectural Research Ltd. for his feedback; and all of those who answered the surveys and were involved in email correspondence.

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