Keeping up with the citizens – collecting earthquake observations in New Zealand

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Abstract

This paper summarises the experiences gained from collecting earthquake felt reports filled out by the general public in New Zealand. With the advent of the Internet, paper-based questionnaires have been replaced with web-based forms allowing for more widespread and efficient use. With a growing number of active users, the underlying software system had to keep up with growing demand and expectations in terms of media, usability, reliability and performance. The integration with social media extended the spread of information when a noticeable earthquake occurs. Based on public feedback, a conceptual shift had to be taken; away from a detailed text-based form towards an easy to use, cartoon-based rapid version that is deployed on a web site as well as part of a mobile app, called Felt Rapid.

With the shift having taken place in 2016, only a few months before the devastating Kaikoura earthquake and its numerous aftershocks, usage numbers have gone up significantly. First results indicate that this increase is in part due to the simplification of the user interface. Future analysis is required to quantify the effect of the latest version of Felt Rapid on user uptake. It is crucial to maintain a reliable operational service in the long term to find out what further measures are required to keep usage numbers up so that valuable reporting data can be collected.

Keywords: citizen science, earthquake reports, GeoNet, New Zealand.

1 Introduction

Earthquakes are a significant natural hazard in many regions of the world. While most earthquakes are typically too small to be felt by a person, occasional events are very powerful and destructive to infrastructure or even people. It is for those large events that one would expect a major motivation for the public to be informed about an earthquake's impact. But information flows in both directions, as many people feel motivated to provide and share information with peers and experts using social media or other Internet-based systems, which means they participate in citizen science.

Recent studies suggest that there are several varying aspects to the motivation of citizen science, with the most common one being of altruistic nature: people want to help, contribute to scientific knowledge or they feel that participating is a valuable thing to do (Geoghegan et al., 2016). Major non-altruistic factors are sharing enthusiasm, personal enjoyment, gaining new knowledge or enhancing the own career (Geoghegan et al., 2016). Several studies have shown that different aspects encourage the continued participation in citizen science projects, such as receiving feedback, enjoyment of the interaction with the system interface as well as noticeable impact and contribution (Geoghegan et al., 2016).

In order to increase the likelihood of users to keep being motivated to use a tool, these factors need to be taken into account when designing or upgrading a system for citizen science. A state-of-the-art tool not only uses the most appropriate technology to connect with people, but provides a great user experience as well (Haklay and Tobón, 2003).

1.1 History of New Zealand earthquake observations

New Zealand with its unique location and geological setting is subject to more than 20,000 detectable earthquakes in average per year.

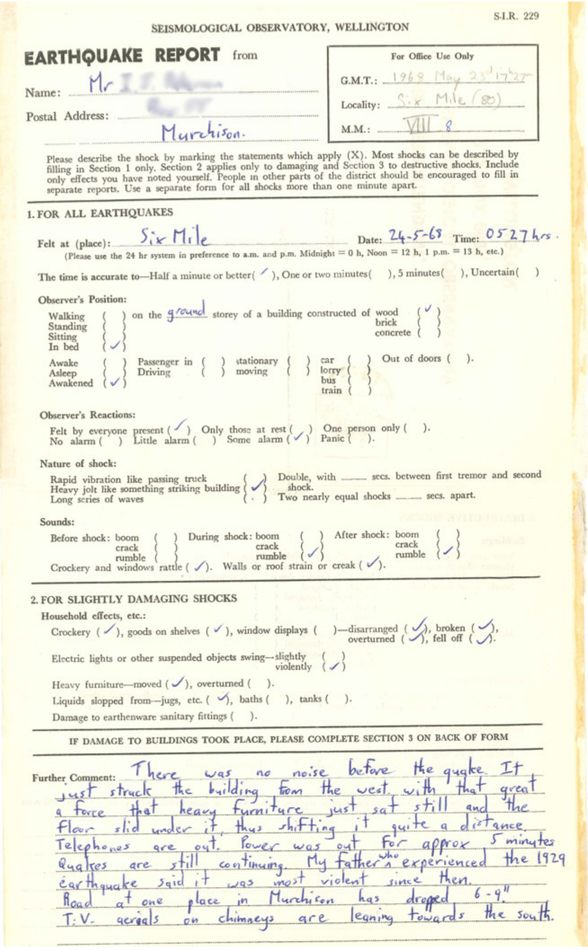
People's experiences during earthquakes have been collected in New Zealand since the late 1800s. Before New Zealand had a robust network of seismographs, felt reporting was the only way to estimate the impact of earthquakes and produce isoseismal maps of shaking intensity. The telegraph network offered an opportunity to quickly gather information on earthquakes felt in different parts of the country. Telegraph operators were asked to instantly send information on any earthquakes they felt. From about 1900 onwards, paper reports became more common, as postmasters and lighthouse keepers had the public duty to submit their reports on earthquakes. Over time, paper forms have been improved and standardised to keep up with the scientific progress. An example of a paper form from 1968 is provided in Figure 1.

1.2 Internet-based reporting

The effect of an earthquake on the Earth's surface is quantified using the Modified Mercalli Intensity Scale (Wood and Neumann, 1931). It has been revised and adapted a few times to accommodate for individual regions of the world (Dowrick and Rhoades, 2005; Grünthal, 1998).

A machine-readable questionnaire, developed by G. Downes and D. Maunder in 2000, was an entirely revised and expanded set of questions based on Dowrick's version of the Modified Mercalli Intensity (MMI) scale (Coppola et al., 2010; Dowrick and Rhoades, 2005).

Figure 1: Earthquake observation report from 1968.



S.I.R. 229

SEISMOLOGICAL OBSERVATORY, WELLINGTON

EARTHQUAKE REPORT from

Name: Mr [illegible]

Postal Address: [illegible]

Murchison.

For Office Use Only

G.M.T.: 1968 May 23rd 17h27m

Locality: Six Mile (80)

M.M.: VIII 8

Please describe the shock by marking the statements which apply (X). Most shocks can be described by filling in Section 1 only. Section 2 applies only to damaging and Section 3 to destructive shocks. Include only effects you have noted yourself. People in other parts of the district should be encouraged to fill in separate reports. Use a separate form for all shocks more than one minute apart.

1. FOR ALL EARTHQUAKES

Felt at (place): Six Mile Date: 24-5-68 Time: 0527 hrs.

(Please use the 24 hr system in preference to a.m. and p.m. Midnight = 0 h, Noon = 12 h, 1 p.m. = 13 h, etc.)

The time is accurate to—Half a minute or better(✓), One or two minutes( ), 5 minutes( ), Uncertain( )

Observer's Position:

Walking ( ) Standing ( ) Sitting ( ) In bed (✓) on the ground storey of a building constructed of wood (✓) brick ( ) concrete ( )

Awake ( ) Asleep ( ) Awakened (✓) Passenger in ( ) Driving ( ) stationary ( ) moving ( ) car ( ) lorry ( ) bus ( ) train ( ) Out of doors ( ).

Observer's Reactions:

Felt by everyone present (✓) Only those at rest ( ) One person only ( ).
No alarm ( ) Little alarm ( ) Some alarm (✓) Panic ( ).

Nature of shock:

Rapid vibration like passing truck ( ) Heavy jolt like something striking building (✓) Long series of waves (.) Double, with ...... secs. between first tremor and second shock. Two nearly equal shocks ...... secs. apart.

Sounds:

Before shock: boom ( ) crack ( ) rumble ( ) During shock: boom ( ) crack ( ) rumble (✓) After shock: boom ( ) crack ( ) rumble (✓)
Crockery and windows rattle (✓). Walls or roof strain or creak (✓).

2. FOR SLIGHTLY DAMAGING SHOCKS

Household effects, etc.:

Crockery (✓), goods on shelves (✓), window displays ( )—disarranged (✓), broken (✓), overturned (✓), fell off (✓).

Electric lights or other suspended objects swing—slightly ( ) violently (✓)

Heavy furniture—moved (✓), overturned ( ).

Liquids slopped from—jugs, etc. (✓), baths ( ), tanks ( ).

Damage to earthenware sanitary fittings ( ).

IF DAMAGE TO BUILDINGS TOOK PLACE, PLEASE COMPLETE SECTION 3 ON BACK OF FORM

Further Comment: There was no noise before the quake It just struck the building from the west with that great a force that heavy furniture just sat still and the floor slid under it, thus shifting it quite a distance. Telephones are out. Power was out for approx 5 minutes Quakes are still continuing. My father who experienced the 1929 earthquake said it was most violent since then. Road at one place in Murchison has droped 6-9" T.V. aerials on chimneys are leaning towards the south.

It became clear in the early stages of its development that the growing use of the Internet by the general public suggested a more effective means of obtaining data. A working example of a semi-automated felt reporting system was already operational in the United States (Wald et al., 2011), and other countries were to follow.

With the widespread adoption of the Internet after 2000 and the introduction of GNS Science's web site detailing felt earthquakes after 1998, the first unsolicited felt earthquake reports began to arrive via e-mail. Despite requesting specific observational details, it was found that e-mails generally contained insufficient information upon which to reliably assign an MMI value.

The aim was to make felt earthquake reporting widely accessible and to design a questionnaire that was objective (i.e., one that was based on effects rather than people's perception of the strength of shaking). In this way, an intensity value could be automatically assigned to an earthquake report. An application was launched in March 2004, with web site visitors accessing the questionnaire through links shown on earthquake report pages. In response to feedback, the questionnaire went through several revisions to improve its usability and to remove the more subjective assessments, such as asking the person filling out the report to classify the earthquake as mild, strong, or violent, which could occasionally lead to the assignment of an unreasonably high intensity value. The success of capturing felt earthquake reports via the Internet led to the cessation of the paper-based reporting network. All remaining earthquake respondents as of June 2005 were advised that it was no longer necessary for them to use the paper forms to report their experiences, and they were encouraged to use the Internet form instead (Coppola et al., 2010).

2 Felt reporting in New Zealand today

2.1 The paradigm shift towards usability

It became apparent to GeoNet that the felt reports most important to researchers – experiences of damaging shaking – were only sparsely reported when they occurred. Prior to 2016, the earthquake with the highest number of felt reports was a magnitude 3.9 earthquake in New Zealand's largest city, Auckland, where earthquakes are rare. The quake had 13,787 reports compared to the devastating February 2011 M6.3 Christchurch earthquake with 3,776. Although Auckland has a larger population (1.4 million) than Christchurch (360,000), felt reports from the Christchurch quake spanned much of the country. Understandably, sitting at a computer and completing an online felt report wasn't a priority for people directly after the devastating earthquake. The current felt reporting system was not meeting researchers' or the public's needs. While the detailed questionnaire with very specific questions was very useful for qualitative analyses, the time required to fill it out proved to be too much of an obstacle.

GeoNet decided to implement 'Felt Rapid', felt reporting that was intended to be quick and simple. Respondents simply had to pick from 6 cartoon images (MMI 3-8) with a short description that best represented what they felt. Reporting also had to be completed within an hour of an earthquake. The use of GeoNet's automatically compiled felt reporting maps had evolved; their main purpose is immediate assessment of an earthquake's impact on populations. When a damaging earthquake occurs and researchers want to collect important and rare damaging felt reports, a separate in-depth survey is commissioned. This is targeted to areas that experienced the highest levels of shaking. These surveys are distributed via a range of mediums including posted as well an online call for submissions.

2.2 Leveraging social media

GeoNet user numbers have grown consistently for several years. The project manages its own profiles on Twitter (>63,500 followers) and Facebook (>101,000 likes). The GeoNet mobile app for Android and iOS is actively used on >359,500 devices. For New Zealand's population of 4.76 Million, these numbers suggest a relatively high percentage of social media users amongst the population of the country.

Each noticeable earthquake is immediately collected, processed and published to all users that are subscribed to any supported media channels.

Figure 2: Felt Rapid's cartoon representation of 'light shaking' in an earthquake.

Users of the mobile app receive push notifications if they wish to and configure the app's notifications accordingly. When receiving a notification, with the click of a button users will be guided to a page that allows them to enter and submit a felt report instantly. App users do not need to type in their location (a vital component of felt reports) as this is already collected via the device. As a response to their submission, respondents will be "rewarded" by showing the felt report amongst all others on an interactive map.

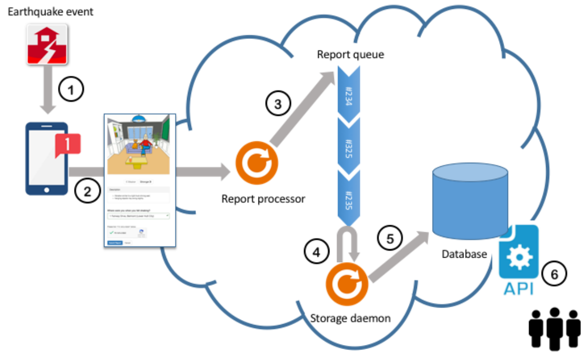
2.3 Service reliability and performance

Users expect a web-based service to be available and responsive at any given time. With an increasing number of users, GeoNet occasionally experienced issues regarding the availability of background services and the web site. With migrating the entire system to the cloud, the provision of content delivery networks, smart caching and performance-focussed implementation of the software, most of the existing bottleneck issues could be resolved.

The reporting process triggers a number of tasks that need to be executed in sequence before the report is stored in the database and report data is available. Figure 3 shows this process chain.

The automated earthquake monitoring system triggers push messages to be sent to subscribed users of the mobile app (1), and at the same time sends notifications to Twitter and Facebook. This process allows for the maximum level of awareness amongst users of any of GeoNet's services. Push notifications are sent within a few seconds of the earthquake being recorded.

Figure 3: Simplified system architecture of Felt Rapid.



The web site is updated with a link to a page that allows entering a felt report. Users can then fill out and submit a report (2), which will be verified and processed by the report processor in the cloud. As large earthquake events trigger a large peak in reporting numbers, all submissions will be added to a queue first (3) so that no information is lost, independent of the availability of the storage service. A storage daemon makes sure that reports are read from this queue (4) and stored in the database. From this moment on, all data related to this particular felt report is available to everybody via an API. All information components on the public GeoNet web page and mobile app (tables, diagrams, interactive maps) are compiled by requesting endpoints of this API, including the instant result map that is rendered as a reward on the user's device.

2.4 Open data for the community

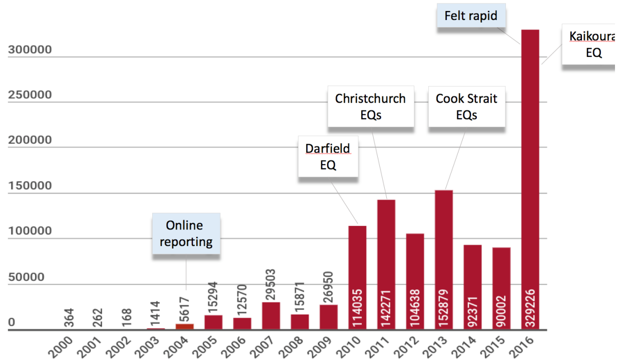
GeoNet's approach is to make all data available free of charge to facilitate research into hazards and assessment of risk. This is realised by publishing information and metadata on the main web site and mobile app. The social media channels ensure that users are made aware of any content updates, and provide links to be navigated to the website resources.

In order to use any raw data, such as the individual felt reports being submitted, GeoNet provides a well-documented API (https://api.geonet.org.nz). A typical query would request all reports for a particular quake, returned as a GeoJSON response snippet. While GeoNet focuses on presenting information on its web page in a summarised form, this API is the resource for further research about earthquake reports.

3 User participation results

The number of annual reports increased significantly with the introduction of the classic web-based system in March 2004: from a few hundred to a few thousand in the first year, and by another order of magnitude in the following years (Figure 4). With the Canterbury earthquakes in 2010 and 2011, the number of felt earthquakes and heightened awareness of GeoNet helped increase this number to around 100,000 each year.

Figure 4: Number of submitted earthquake reports in New Zealand between 2000 and 2016.



The outstanding number of reports in 2016 (329,226) can be explained mainly with the devastating Kaikoura earthquake and its enormous aftershock sequence, which accounts for more than half of all annual reports. But even within the preceding months, usage numbers have gone up significantly, with more than 50% of users having switched to the new reporting interface by upgrading their app or using the web site.

Table 1: Number of reports for major and highly reported earthquakes since 2003.

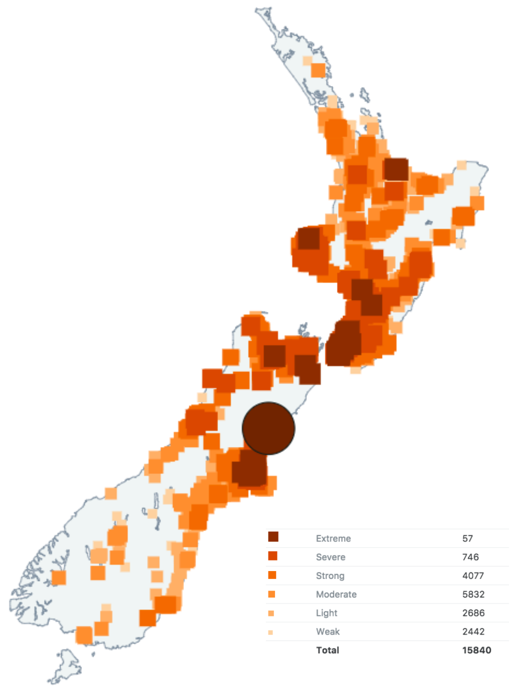
Earthquake	Felt It?	Felt Rapid	Felt Detailed
2003 M7.1 Te Anau	403		
2004 M7.0 Snares Is	806		
2009 M7.8 Dusky Sound	2,947		
2010 M7.2 Darfield	6,936		
2011 M6.3 Christchurch	3,778		
2013 M4.0 Auckland	13,787		
2013 M6.5 Grassmere	6,178		
2016 M7.1 Te Araroa*		4,711	415
2016 M7.8 Kaikoura		15,840	3,485
2017 M4.8 Paraparaumu		11,022	n/a

* The Te Araroa Earthquake was during the switch to the new system of reporting, causing some technical issues meaning Felt Reporting stopped working for a time and Felt Detailed was also delayed.

The shift towards Felt Rapid indicates to trigger an increase in participation. For example, an earthquake of M4.2 in 2011 resulted in a response of 1,522 reports, while a similarly sized quake (M4.3) in late 2016 has been reported by 4,130 users. In March 2017, a moderate earthquake near Paraparaumu (M4.8) resulted in 11,022 reports.

Figure 5 shows the spatial distribution of Felt Rapid reports within one hour of the devastating Kaikoura earthquake in 2016, which was felt in most parts of the country. It shows the relative low number of reports being submitted from the area around the epicentre.

Figure 5: Earthquake reports for the 7.8 Kaikoura earthquake on November 14 2016 (n=15840). This map is available on the website https://www.geonet.org.nz.



4 Conclusion and Outlook

Geological Surveys around the world run earthquake reporting services to engage with the public (BGS, 2017; USGS, 2017). With the rapid development in Internet technologies comes a growing demand for a great user experience in software products and services. People expect high quality services that deliver in terms of performance and reliability. For the concept of citizen science, it is important to reach a critical size of spatially distributed data set. Making it easy for the users to provide input has proven to be a major factor to reach this goal.

Over the course of several decades, the GeoNet project and its predecessors have adapted its citizen science approach continuously based on user feedback and usage metrics. The current approach for collecting earthquake information from the public makes use of the most simplified user interface that the project team could think of. While the more detailed information cannot be collected instantly the provision of event-specific 'Felt Detailed' reporting facilities caters for this demand in specific cases.

It is important to notice that the awareness on reporting importance has changed since the Canterbury earthquakes in 2011 and 2012, which is likely to have a significant effect on increased reporting numbers for both, Felt Rapid and Felt Detailed.

The feedback from the felt reports will continue to be analysed in terms of potential improvements to keep both the quality and the high reporting numbers up. More research is necessary to find the right level of integration between 'Felt

Rapid' and 'Felt Detailed' with respect to quake intensity, aftershock sequences and location. Results so far have shown that proximity to major cities with their large population is the major parameter that determines the number of reports. Research on how to stratify for this and other effects would be valuable for both the GeoNet team as well as the science community.

References

BGS. *BGS E-Mail Earthquake Questionnaire*. [Online] Available from: http://earthquakes.bgs.ac.uk/questionnaire/EqQuestIntro.html [Accessed 6th February 2017]

J.M. Coppola, L.X. Cowan, G.L. Downes, K.F. Fenaughty, P.D. Grimwood, P. Leach and E. de J. Robertson. Felt Earthquake Reporting via the Internet in New Zealand. *Seismological research letters*, 81(6): 984-991, 2010

D. J. Dowrick and D. A. Rhoades. Revised models for attenuation of Modified Mercalli intensity in New Zealand earthquakes. *Bulletin of the New Zealand Society for Earthquake Engineering* 38, 185–214, 2005.

H. Geoghegan, A. Dyke, R. Pateman, S. West and G. Everett. Understanding Motivations for Citizen Science. In: *Final Report on Behalf of UKEOF*, University of Reading, Stockholm Environment Institute (University of York) and University of the West of England, 2016.

G. Grünthal. European Macroceismic Scale 1998 (EMS-98). *Cahiers du Centre Européen de Géodynamique et de Séismologie*, Vol. 15, Luxembourg, 1998.

M. Haklay, and C. Tobón. Usability evaluation and PPGIS: towards a user-centred design approach. *International Journal of Geographical Information Science*, 17(6), 2003.

USGS. *Did You Feel It?* [Online] Available from: https://earthquake.usgs.gov/data/dyfi [Accessed 6th February 2017]

D.J. Wald, V. Quitoriano, C.B. Worden, M. Hopper and J. W. Dewey. USGS "Did You Feel It?" Internet-based Macroseismic Intensity Maps. *Annals of Geophysics*, 54, No. 6, 2011.

H. O. Wood and F. Neumann. Modified Mercalli Intensity Scale of 1931. *Bulletin of the Seismological Society of America*, 21, 277-283, 1931