Emergency Situation Awareness from Twitter for Crisis Management

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ABSTRACT

This paper describes ongoing work with the Australian Government to detect, assess, summarise, and report messages of interest for crisis coordination published by Twitter. The developed platform and client tools, collectively termed the Emergency Situation Awareness - Automated Web Text Mining (ESA-AWTM) system, demonstrate how relevant Twitter messages can be identified and utilised to inform the situation awareness of an emergency incident as it unfolds.

A description of the ESA-AWTM platform is presented detailing how it may be used for real life emergency management scenarios. These scenarios are focused on general use cases to provide: evidence of pre-incident activity; near-real-time notification of an incident occurring; first-hand reports of incident impacts; and gauging the community response to an emergency warning. Our tools have recently been deployed in a trial for use by crisis coordinators.

Categories and Subject Descriptors

H.4 [**Information Systems Applications**]: Miscellaneous

Keywords

Situation Awareness, System Architectures, Social Media, Disaster Management, Crisis Coordination

1. INTRODUCTION

Crisis coordination is the process undertaken by organisations and individuals aiming to reduce the impacts communities experience from exposure to hazards during real world incidents. In large scale crises, understanding the impact of incidents is critical for the successful restoration and recovery of safety and essential services. The Australian Government Crisis Coordination Centre (CCC) is a 24/7 all-hazards management facility which supports protective security, counter terrorism, pandemics, and the monitoring and reporting on natural hazards and other emergency management incidents. Each state and territory in Australia is responsible for its own preparation and response to natural disasters. When the local authorities are unable to cope with a large scale emergency or disaster, the CCC coordinates assistance [1].

The CCC monitors domestic and international media for developments relating to national security and emergency management incidents. Social media provides a new source of data from which crisis coordinators can obtain awareness of developing situations. This information has many potential applications within emergency management and crisis coordination. Our work uses near-real-time information from Twitter collected during and after incidents to inform and corroborate post incident impact assessments.

The rest of the paper is organised as follows. We first introduce background information about crisis coordination and situation awareness, followed by a description of the problem being addressed. Then the tools we have developed are presented along with a description of a trial deployment. The conclusion provides a summary of our work.

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2. CRISIS COORDINATION & SITUATION AWARENESS

The core function of the CCC is to manage the flow and transformation of verified information for stakeholders. The CCC has policies and procedures for the tasks to be undertaken during emergency events. Part of this process is the gathering, processing, compiling, recording, and reporting of information from various sources. The information received is *verified*; it is from authoritative agencies and obtained as *incident reports*. All communication received or produced is recorded in an *incident log* by the watch officer, the person at the front line of information processing during an emergency event. The core operational processes of the CCC require verifiable facts, with the incident log recording "who knew what when".

Watch officers seek to understand the scope and impact of all hazards throughout the prevention, preparedness, response, and recovery phases of crisis management. To support the information management goals of: "Deliver the right information to the right people in the right format in the right place at the right time." [4], we turn to the Endsley [2] model of situation awareness.

In that model the "state of the environment" is connected into a feedback loop through Situation Awareness, Decision (Making) and (Performance of) Action. Situation awareness itself has three levels: level 1 (Perception); level 2 (Comprehension); and level 3 (Projection). Perception is about picking up sensory cues from the environment. Comprehension involves combining sensory cues and interpreting the information. Projection deals with forecasting what might happen next.

Understanding a situation rests on identifying an appropriate set of perception elements, higher level comprehension patterns/templates and forecast operators. A situation awareness system understands its environment at multiple levels: from the Perception of events in raw data streams, to Comprehension of situations, through to Projection (or prediction) of likely futures [5].

Situation awareness for crisis coordinators involves scanning the environment for perception cues; reasoning about these cues, connecting, hypothesizing, testing and ultimately comprehending these cues; and finally, forecasting what might happen next. Maintaining situation awareness of an incident allows watch officers to effectively plan and implement responses, anticipate and manage requests for information about incidents.

While the CCC will not consider information gathered from social media as an authoritative source, it does provide an additional source of perception cues and assists to establish situation awareness. Watch officers may use Twitter and other social media in an ad-hoc fashion as an additional source of information.

3. THE PROBLEM

Social media is a new source of information from the general community. This information can be used to inform and corroborate traditional sources of information to provide an enhanced situation awareness for emergency managers to successfully restore safety and essential services.

Watch officers have a limited amount of time to scan and assess if information is worthy of deeper analysis. Social media can provide a rich source of information about an incident, but the problem of converting this large stream of data into useful situation awareness information remains.

Crisis coordinators need tools and services that mine social media to address the following needs:

1. Detect unexpected or unusual incidents, possibly ahead of official communications;
2. Condense and summarise messages about an incident maintaining awareness of aggregated content without having to read individual messages;
3. Classify and review high-value messages during an incident (e.g. messages describing infrastructure damage or cries for help); understand the impact of an incident on people and infrastructure;
4. Identify, track, and manage issues within an incident as they arise, develop, and conclude; pro-actively identify and manage issues that may last for hours, days or weeks;
5. Perform forensic analysis of incidents by analysing social media content from before, during, and after an incident.

4. ESA-AWTM

The following is a description of the ESA-AWTM architecture and the main components that address the needs of the watch officer as described above.

4.1 Architecture

Figure 1 is a schematic diagram of the ESA-AWTM platform and client tools. The *Source* components (green) are responsible for capturing tweets from the Twitter search or stream API. These tweets are assembled into a *capture message*, which is pushed into the ESA-AWTM *Infrastructure* (purple) and distributed to other infrastructure and *Process* (tawny) components through a Java Message Service broker. The client tools (blue), also referred to as the *Browser Presentation* component, use web services to retrieve and display information to a watch officer. All interactions between the watch officer and the ESA-AWTM platform are through intranet HTTP requests.

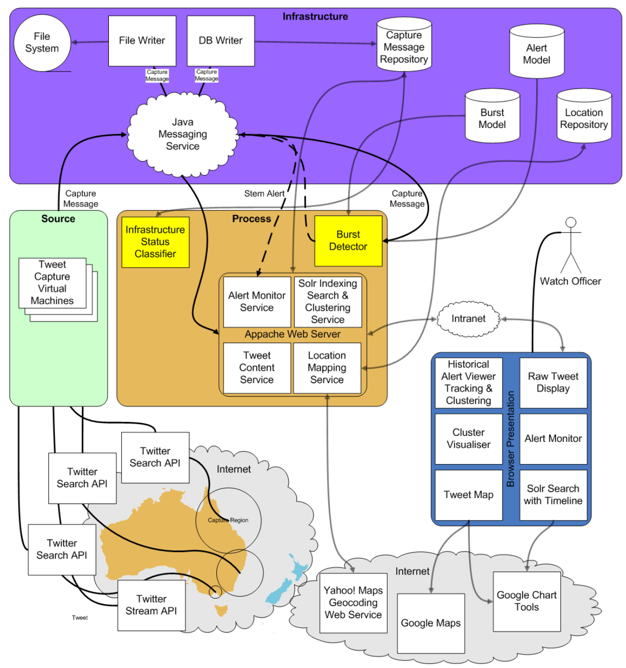

Figure 1: System Design Schematic.

The infrastructure components include file and database writing services. By carrying out its own tweet capture and storage, the ESA-AWTM platform makes available more metadata than is available via the Twitter API. The tweet content and metadata is accessible via a simple database connection and analysis can be performed locally.

Processing components include our burst detector and infrastructure status classifier. Capture messages are processed by the burst detector, location mapping services, and an indexing search and clustering service. The tweet content service provides access to our database repository of capture messages.

4.2 Meeting Watch Officer Needs

The five watch officer needs identified in Section 3 are addressed by the ESA-AWTM platform as described below.

4.2.1 Detect Incidents

The burst detection method examines the stemmed unigram words in the tweets using a parameter-free method [3]. It uses historical data to build a statistical model of word occurrences. A burst is defined as a positive variation from this statistical model. We coupled this burst detection method with a complex event processing infrastructure to enable continuous monitoring of all messages from our data capture framework. The burst detection service provides watch officers with basic situation awareness at a perception level. Figure 2 shows our burst visualisation for a small 4.4 magnitude earthquake in Melbourne in July 2011 where the colour and size of the alert word indicates the strength of the burst.

Figure 2: Alert Monitor.

4.2.2 Condense and Summarise Messages

When a watch officer decides to investigate an alert, we need to provide a way for them to gain a rapid understanding of topics within bursting words. Condensing and summarising messages provides watch officers with basic perception level situation awareness. We integrated a third party clustering engine, Carrot[2], with an open-source search engine, Apache Solr, to enable clustering sets of tweets. We developed an interface to display the resulting clusters as shown in Figure 3 for the same event as above. The display shows cluster summaries with font size and colour used to indicate the relative number of tweets participating in the cluster.

Figure 3: Cluster Visualiser.

4.2.3 Classify and Review High-Value Messages

We have developed a system that can automatically classify tweets as interesting or not. Our classifier, based on Support Vector Machines [6], is trained to identify "infrastructure damage" tweets, which has been successfully tested using a collection of tweets retrieved during the February 2011 earthquake.

This technique is different to a keyword-search approach in that it starts with a set of labelled examples and then applies machine learning techniques to "learn" a statistical model of what to look for. It is possible to combine the statistical classification output with condensing and summarising approaches discussed above. For example, we can just summarise tweets that have been classified to be relevant to infrastructure damage.

The classification system provides watch officers with a more targeted view of information during an incident. Our challenge is to adapt our classifiers to address other types of natural hazards, such as bushfires, cyclones, and floods.

4.2.4 Identify, Track, and Manage Issues

Assisting watch officers with incident comprehension within an all-hazards approach is very challenging. We are attacking this challenge by first exploring how to cluster messages and topics together over time. Our intuition is that during an ongoing incident, issues arise, merge, split and dissipate. Our approach to tracking issues has been to develop a new incremental clustering algorithm. The algorithm is able to condense or merge message clusters with similar content, split clusters with dissimilar content, and delete clusters once they have become uninteresting. The algorithm is guided by the burst detection framework which enables temporal cluster management to string clusters together over time. Evaluation of this algorithm and approach is the subject of ongoing work.

4.2.5 Forensic Analysis

Our capture and storage infrastructure enables off-line analysis of the tweet corpus. For forensic analysis, it is useful to be able to "replay" alerts generated by the near-real-time burst detector. The generated alerts are written to a database which can be accessed later by our "Historical Alert Viewer" tool. The user can enter a specific date and hour, then use a time slider to step forward or backwards minute by minute. The alert display is automatically refreshed as the time slider moves. The Historical Alert Viewer can also display the tweet clusters for a selected alert.

4.3 Tweet Captures

The tweets of interest for the CCC are obtained using the Twitter search API by defining a location and search radius to cover most of Australia and New Zealand as shown in Figure 4. The markers on the map show the locations of the source tweets and below the map are two related timelines showing the volume of tweets captured. These timelines show the number of tweets received for each five minute window and they are automatically updated every five minutes. The user can zoom into a region of the timeline by using the sliders at the bottom.

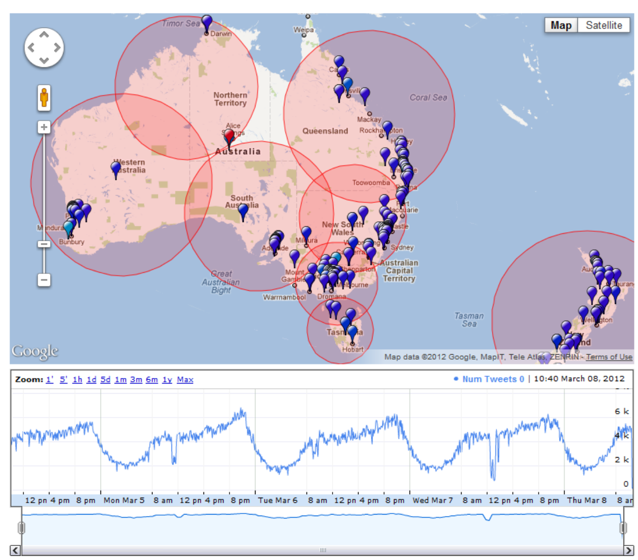

Figure 4: ESA-AWTM Captures and Tweet Map.

When tweets are not geo-coded, an attempt is made to geo-locate them based on the user's profile location. The watch officer can then click on a marker to view the recent tweets from that region. The markers are coloured to indicate the volume of tweets received from that location.

5. DEPLOYMENT EXPERIENCE

A subset of our tools have been deployed for trial by the Media and Crisis Communication team within the Strategic Communication Branch (SCB) of the Australian Government Attorney-General's Department. This Branch is responsible for whole-of-government national security media coordination.

As our system has a complex configuration and many distributed components, the easiest way to set up this trial was to make our web applications externally visible to the communications team. However, our original design assumed the system would be deployed within an intranet. Making the system available via the Internet would violate Twitter's Developer Rules of the Road[1]. In particular, developers are not allowed to re-publish Twitter Content (i.e. tweets) that they have collected.

The communications team are most interested in our Burst Detector/Alert Monitor interface where coloured alerts are displayed when bursting words are detected, so this interface was re-engineered to retrieve, cluster, and display tweets related to each alert directly from Twitter on the fly. We were initially concerned that the performance would be unacceptable, since each click on an alert generates several Twitter Search API calls. However, the interface has proved to be very responsive with results for each selected alert displaying in under a second. Note that by re-engineering the client tool to retrieve and display tweet content directly from Twitter only tweets from the last six days are available. This is not a limitation when using our tweet repository. Feedback from the SCB will help refine the utility of our tools.

Figure 5 shows a screenshot of the deployed interface. The user is able to "Monitor Latest Alerts" where the alerts are updated every minute, or "View Historical Alerts" where alerts generated at a particular point in time can be viewed. Note that the source tweet content, the user's image, and screen name have been deliberately blurred. When in "View Historical Alert" mode the user can replay a series of alerts using the Play and Pause buttons as described in Section 4.2.5.

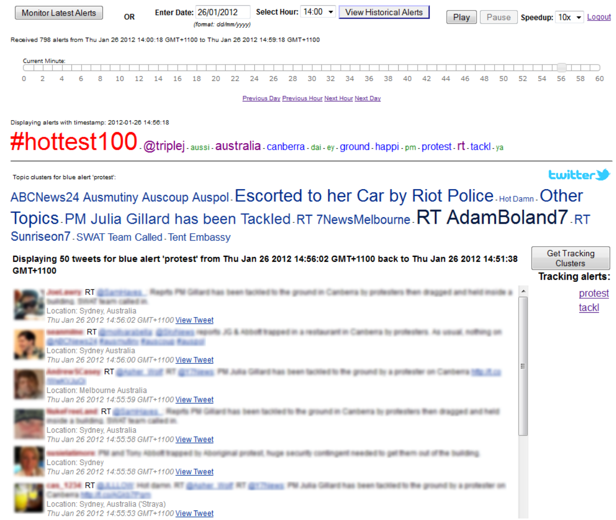

Figure 5: Deployed Interface.

6. CONCLUSIONS

The increasing use of social media is changing the way people communicate. During emergency situations, information is available from the public that can be utilised to inform the situation awareness of emergencies to help crisis coordinators respond appropriately. This information will not replace existing procedures and information sources, but it can provide a new source of data that has many potential applications within emergency management and crisis coordination. Examples where social media can play a role include providing: evidence of pre-incident activity; near-real-time notification of an incident occurring; first-hand reports of incident impacts; and gauging the community response to an emergency warning.

The CCC has previously monitored social media in an informal or ad-hoc fashion. This requires watch officer personnel to actively pursue information using web sites not tailored specifically to their needs. Our tools formalise the way in which the CCC can utilise the information available on Twitter. The tools are configured for tweets originating from Australia and New Zealand and processed to identify messages of interest to watch officers responsible for the front line of information processing during an emergency event.

[1] `https://dev.twitter.com/terms/api-terms`

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