Fire Hazard Notifications via Satellite, Twitter, Citizen Reports, and Android Apps

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Abstract

Humanity has had a long historical relationship with fire. According to anthropologists, the first humanoid species learned to use and control fire approximately two million years ago. *Using* fire and *controlling* fire, however, are dramatically different operations. From prehistoric times, uncontrolled fire has brought death and destruction. In more recent historical times, the Roman Empire used slaves and conscripts to fight fires. Since slaves and conscripts did not have the same interest in preserving the empire as freemen, subsequent firefighting organisations in the Roman Empire used freemen instead of slaves. In even more recent history, many countries have a proud history of having a volunteer firefighting force. Regardless, however, of whether it is slaves, conscripts, freemen or volunteers who fight the fire, early detection of the fire is critical. In the presence of dry fuel, the right atmospheric conditions and a source of ignition, wildfires spread easily and quickly. This paper describes a project which combines satellite imagery with crowdsourced fire information collected from citizens and residents in order to provide a fire hazard notification system to participants.

Keywords

fire, hazard, mobile, android, citizen report, twitter

7. Introduction

People have had a long historical relationship with fire. According to anthropologists, *Homo erectus* was the first human species to use fire nearly two million years ago (Leakey, 2008, pp. xiv) and acquired the knowledge to start and stop fires (Pyne, 1998, pp. 64). In South Africa, Swartkrans cave shows some of the earliest evidence of fire being used by humanoids (Brain & Sillent, 1988; James, 1989).

Using fire and *controlling* fire, however, are different things. From prehistoric times, uncontrolled fire has brought death and destruction. In more recent documented historical times, accounts from the ancient Roman Empire describe community efforts to suppress uncontrolled fire in 24 B.C. when emperor Augustus Ceasar created what was probably the first fire department which consisted of approximately 600 slaves and conscripts. Slaves and conscripts, however, often have no real personal interest in preserving the property of their owners and captors. In approximately 60 A.D., emperor Nero established a core of 7,000 freemen (and not slaves) who were responsible for fire prevention, firefighting, and building inspections (International Association of Fire Chiefs & National Fire Protection Association, 2008, pp. 10).

Many countries have a proud tradition of volunteer fire departments manned by the citizens in the area. In 1736, before he became one of the founding fathers of the United States, Benjamin Franklin established the first volunteer fire department in North America. According to historian Libby O'Connell, this volunteer fire department offered citizens "...an opportunity to improve their city and themselves". She explained that "You don't just look to the government; you have to look to your community to pitch in and help" (Cohen, 2012).

Fires grow rapidly if there is enough oxygen and fuel (in a condition suitable for burning). Certain atmospheric conditions such as low relative humidity and high wind exacerbate fire spread. Early detection is key to successfully controlling a

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fire. Throughout history, the attempt to detect fires early, has led to many innovations – some more precarious than others as can be seen in Illustration 1 (Zimmerman, 1969, pp. 5).

This paper describes a fire hazard warning system which uses satellite imagery combined with crowdsourced citizen reports published on Twitter and published via a specific mobile phone app. The mobile phone app serves dual purpose of providing an easy channel in which to publish citizen reports of fires and to warn the people of nearby fire hazards.

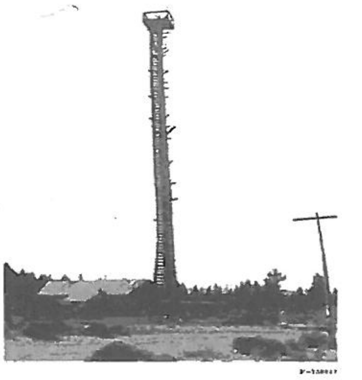

Illustration 1: Lookout Tower, circa 1921

8. Economic Impact of Uncontrolled Fires

The Fire Protection Association of Southern Africa (FPASA) was established in 1973 and provides specialised fire related information and services to South African industry, commerce, and society at large. It publishes annual reports about fire statistics in South Africa (FPASA, 2013a).

In June, 2013, FPASA published the results of their extensive analysis of fire related incidents for the year 2011 (FPASA, 2013b) in which they categorise types of fires, fire brigade names (including municipalities), monetary values of loss, and lives lost. According to their report, in 2011, there were 37,721 related fire incidents in South Africa, in which 410 people lost their lives. Their calculation of Rand value damage was just over two billion Rand (R2,085,522,959) for the year of 2011.

Fire information systems in South Africa observe many thousands of wildfires each year, a significant number of which are threats to infrastructure (e.g. electricity transmission lines and transport corridors), human and animal life as well as vegetation and soil (McFerren & Frost, 2009).

From these statistics it is clear that if a citizen augmented early warning system could be successfully implemented, there could be a social benefit and business benefit to South Africa.

9. Architecture

The path of information between the various components can be seen in Illustration 2.

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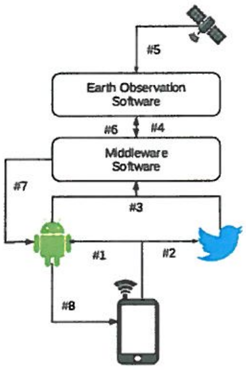

Illustration 2: Flow of Information

When person with a cell phone observes a fire hazard, he or she can either use an Android application (#1) to publish this information or can publish the information on Twitter (#2). In either case, the middleware communication platform receives this information (#3) and forwards it to the Earth Observation platform (#4). Concurrently to this, the Earth Observation platform receives satellite images (#5).

The Android application can also be configured to send periodic location information about the user which is also forwarded to the Earth Observation platform using the same channels. When the Earth Observation platform determines that the Android user is in the vicinity of a fire hazard, a notification is sent to the user (#6, #7, #8).

Each of these steps will be discussed in their own sections.

10. The High Tower – Satellites

The application under discussion accesses fire information from the CSIR Advanced Fire Information System, as described by McFerren & Frost (2009).

Satellite imagery is obtained from computational processing chains over data received via direct broadcast from satellites carrying the NASA MODIS instrument as they pass over a receiving antenna. The processing chains extract geo-located active fire "hotspots" from raw imagery. A hotspot is a pixel that has a relative temperature to the surrounding pixels that exceeds a certain threshold. The algorithm is beyond the scope of this paper. These hotspots may be used as a proxy for fire detection. Each hotspot datum carries attribute information concerning detection time, intensity and geo-location.

Hotspot data are loaded into a geospatial database where they may be queried together with other data sources in order to generate information products and reports. Additionally, the hotspots are placed onto stream/event processing systems where they can be disseminated appropriately as part of early warning alerting systems or incorporated into external systems.

As useful as Earth Observation based systems have proven to be, they currently still suffer from a paradox: if you wish to see data at a high temporal frequency, you must sacrifice spatial resolution; if you want to see data at a high spatial resolution, temporal frequency is compromised. In practice, this means that you can observe large fires often and small fires if you are lucky and a satellite passes overhead at just the right time. To alleviate this paradox, alternative observation sources are required.

11. Android App

One of the purposes of applications on a mobile device is to make life more convenient for the user. The user has the internet to enable him or her to quickly search for a fact, a GPS to easily direct the user to specific locations, and other

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other innovative facilities. With all this, perhaps a citizen could give back to the big world of data by providing important information - especially if it is one button tap.

When driving along the road, a vehicle can easily get stuck in traffic. Traffic can be caused by many things such as accidents, spilled goods, and various other hazards. For this project we looked specifically at one particular type of hazard - fire. There are not many services that report fires. If a driver saw a fire along the road, he or she would have to search the Internet for a phone number and then phone the local fire departments to report it. This is difficult while driving (if not, actually, illegal). Fires spread easily when there is the required fuel, oxygen, and atmospheric conditions. Fire can get close to roads which is dangerous. The smoke from the fires alone can impair the vision of drivers.

One of the main problems is that fire hazards are not easy to report. The mobile application developed for this project enables easy reporting of fire hazards. Once the application has been downloaded and installed, all that is necessary is to sign into Twitter to post tweets about fire hazards that have been spotted. This requires that the GPS is enabled because the location of the hazard needs to be sent out.

An even more important feature is the facility that the application offers to alert the user as can be seen in Illustration 3. There is no need to sign into any social media platform to be able to receive alerts. The application periodically sends the user's GPS coordinates to the Earth Observation platform. If the user is approaching a hazard, a notification will be sent to that user. The user will see the notification in their notification bar. Once tapped, the user will have a text based hazard description, as well as a map view. The map will have both the user's current location and the location of the hazard. This makes it easy for viewing purposes if the user happens to be in slow moving traffic. They could easily see where the hazard is on the map and possibly avoid it by taking an alternate route.

Illustration 3: Sample alert

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12. Crowdsourcing

Jeff Howe is attributed with coining the term *crowdsourcing* in his article in Wired Magazine in 2006 (Howe, 2006). The definition of *crowdsourcing* varies but the definition normally has four components (Alsever, 2007). 1) A group of people 2) provides information 3) usually free of charge 4) to another group of people. Websites such as Wikipedia and Youtube are examples of crowdsourcing.

Obviously, the Internet makes crowdsourcing easy. But in some industries, crowdsourcing has been available for as long as some form of communication is available. In the aviation industry, PIREPS are weather reports provided by pilots in-flight. These are especially important if the weather encountered by the pilot differs from the predictions published by the weather bureaus (Federal Aviation Administration & United States. National Weather Service, 2010).

In this project, crowdsourced data about fires are extracted from two sources. One source is Twitter. Twitter is a micro-blogging website where users can publish 140-character status updates or *tweets* (Kwak, Lee, Park, & Moon, 2010). People tweet about what they see, what they hear, what they experience, what they feel, and what they believe. The second source of data is from a specialised mobile phone app for Android which provides easy posting of a fire hazard with the press of one button. Each of these data sources will be described below.

13. Twitter, Microtext and the μ Model

Twitter is a micro-blogging site where users publish short 140-character status updates (Kwak et al., 2010). Twitter provides a number of APIs which provide functionality for searching and extracting these status updates. It is possible to search by a combination of strings (such as *veldfire, shackfire,* etc), by hashtags (such as *#grassfire*), and by geo-locations (longitude and latitude of locations with a surrounding radius). Twitter provides these searches both synchronously and asynchronously. Currently, at the time of writing this paper, searches for the last 24 hours are free of charge.

Because of the length restriction on posts on Twitter, people resort to using Microtext. According to Ellen (2011), microtext messages are:

1. Very brief perhaps consisting of just a single word or symbol
2. Generally informal and unstructured
3. Has a "minute level" timestamp and an author

Other examples of microtext (besides Twitter) include SMS (Short Message System) and instant messaging.

The μ Model (pronounced "mu" and representing the phrase "microtext understander") is a model for spotting predefined topics in microtext and has been used in applications to spot topics in mathematics (Butgereit, 2012) and to spot topics about the weather (Butgereit, 2014). The model consists of four steps: 1) removal of stop words 2) stemming 3) spelling correction and, finally, 4) topic determination.

A sample tweet can be used to demonstrate this model: #shackFire four shacks up in flames

Stop words are words which can be safely removed from a sentence without changing its fundamental meaning. This operation would transform the post to simply: #shackFire shacks flames

Stemming removes suffixes from the ends of works. This would ensure that words such as *burns, burn,* and *burning* would equate to the same root word. This operation would transform the post to: #shackFire shack flame

In this particular example, all of the words are spelled correctly and no transformation is required. The last step is to compare the remaining words to vocabulary lists to determine the topic.

In this particular project, Twitter was polled every 10 minutes for appropriate tweets around South Africa. Tweets which were deemed by the Middleware to be appropriate, were forwarded to the Earth Observation platform along with any geo-location.

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14. Hazard Notification Generation

In order generate a hazard notification two components are required. First the identification of a potential hazard, such as a veld fire. Second the identification of a entity either a human or some infrastructure that may be placed at risk as a result of that hazard. For instance a car moving along a road that has a veld fire burning next to it.

The hazard and the entity at risk have location and as such these locations may be tested for future intersection. A naïve yet effective test is to place a large bounding area around the hazard and test for any entities that are within this bounding area. Once an intersection has been identified a message is generated and passed to messaging middleware which then forwarded it to the appropriate users running the Android application.

15. Evaluation

Although the evaluation of the technical aspects of the architecture and communication channels is important, of more importance is the evaluation of the human aspects of this project and the way it relates to cybercitizenship.

A number of human issues have arisen which have been detrimental to the evaluation of this project. There are two primary issues.

The first issue is that people do not appear to tweet about fires in their vicinity. This was unexpected. Previous research had shown that people tweet often about the weather (Butgereit, 2014). This phenomenon of tweeting about the weather mirrors the normal human activity of talking about the weather (Harley, 2003; Strauss & Orlove, 2003). The authors had assumed that there would be more activity on Twitter about veldfires, shackfires, and forestfires. Unfortunately, this did not turn out to be true. While there are tweets about fires, in most cases those tweets are generated by news organisations or safety organisations. They were rarely generated by individual people. A superficial search at twitter confirms this fact in other countries which are prone to wild fires including the United States and Australia.

The second issues concerned the use of the GPS on the mobile phone. Very few of the tweets which were extracted contained geo-location information about the sender. The software had to interpret the location from the textual portion of the tweet instead of receiving exact longitudes and latitudes. That means that tweets such as: Huge veldfire rages out of control near Vaalwater.

could not be precisely located on a map since there is no longitude and latitude and the expression "near Vaalwater" is very broad.

Another issue with the GPS concerned using the GPS with the Android app to receive hazard notifications. In order to receive notifications timeously, the participants needed to have the GPS enabled along with the Android app running in order to have his or her location updated timeously on the Earth Observation servers. This severely drained the cell phone battery.

16. Conclusion

Humanity has had a long history of interacting with fire. Throughout history, people have attempted to have fire warning systems and firefighting systems. In the Roman Empire, slaves and conscripts had been used as firefighters even though the slaves and conscripts had no real personal interest in protecting the Empire's assets. In later development, freemen were used as firefighters in the belief that freemen had more vested interests in the surrounding areas. In more recent times, many areas have developed volunteer firefighting departments.

This paper explores the possibility of crowdsourcing citizen reports about fires using both Twitter and a mobile Android application. This information was then merged with satellite images. The satellite images could be used to locate large fires and the croudsourced citizen reports could be used to locate small fires before they grew into large fires. Users who were running the Android application could then receive timeous notifications when there was a fire hazard in their vicinity.

Although the architecture and framework were successfully implemented, there existed certain human characteristics and cell phone characteristics that impeded the success of this project. The primary human characteristic which impeded this project was the fact that very few people actually posted tweets about fires. This is true around the world and is not just a South African characteristic. The primary cell phone characteristic which impeded this project was the fact that keeping the GPS enabled on a cell phone (in order to either report fire hazards or to receive fire hazard notifications) drained the battery unacceptably.

In conclusion, although the technology implementation was successful, the actual project implementation was less successful due to human nature (people do not talk about fires as commonly as they talk about the weather) and due to GPS facilities draining cell phone batteries. The researchers, however, are confident that if a media campaign to encourage people to tweet about fires were undertaken, the first problem could be ameliorated. In addition, as cell phone battery technology advances, the researchers are confident that more and more people will keep their GPS enabled thereby ameliorating the second problem.

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