MODEL OF INTEGRATING SOCIAL MEDIA DATA AND METEOROLOGICAL DATA FOR FLOOD CRISIS SITUATIONAL AWARENESS

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DEDICATION

This thesis is dedicated to my late father and my mother as a gift for their patience and support as I build my career and through my academic journey. I also dedicated this thesis to my husband as a proof of being a successful wife.

ACKNOWLEDGEMENT

ABSTRACT

A flood disaster is the most disastrous hydrological event that can lead to property destruction and loss of lives. Malaysia is one of the countries that face flood disasters every year, which have caused billions of damages and loss of lives. One of the efforts to mitigate the impact is by providing advanced technology in monitoring and event alerts in disaster management. One of the ways to increase disaster management efficiency is by enhancing the situational awareness of the disaster. This study aimed to propose a model that can integrate social media data with meteorological data to improve the situational awareness of flood disasters and effectively communicate flood hazards between communities and authorities. The experimental research design methodology was adopted to design, develop, and evaluate the proposed model. The study first investigated the current standard operating procedure of flood disaster management and continued by studying the features of the social media data that can be employed in this research. Inferential statistic, ANOVA, was used to evaluate and analyse the results. The main contribution of this study is a proposed model comprising four major components: crisis alert, flood awareness, general services, and communication. Findings revealed that all four main components proposed in the model of this study are effective for technology integration in enhancing situational awareness of flood events. The proposed model was validated through a prototype design, which was assessed through usability evaluation. Findings confirmed that the proposed model has the highest mean values for Crisis, Flood Awareness, General Services and Social Media Usage characteristics which is meant that it's been chosen the most by users indicating that the proposed model is capable in providing reliable information during flood crisis as well as enhancing the situational awareness of the event. Further findings of this study also confirmed that there is a significant difference between the component and each platform evaluated. This research has successfully shown that enhancing situational awareness can be one of the ways to mitigate the effect of the flood crisis, and it can be done by integrating social media data with meteorological data, which the main initiative is to include the community in the disaster management. This research has successfully achieved its aim, which is to enhance the situational awareness of flood crises and provide effective communication towards flood hazards through social media data integrated with meteorological data.

ABSTRAK

Bencana banjir adalah peristiwa hidrologi yang paling dahsyat yang boleh membawa kepada kemusnahan harta benda dan kehilangan nyawa. Malaysia merupakan antara negara yang setiap tahun menghadapi bencana banjir yang menyebabkan berbilion-bilion kerosakan dan kehilangan nyawa. Salah satu usaha untuk mengurangkan kesan adalah dengan menyediakan teknologi termaju dalam pemantauan dan amaran kejadian dalam pengurusan bencana. Salah satu cara untuk meningkatkan kecekapan pengurusan bencana ialah dengan mempertingkatkan kesedaran situasi bencana. Kajian ini bertujuan untuk mencadangkan model yang boleh mengintegrasikan data media sosial dengan data meteorologi untuk meningkatkan kesedaran situasi bencana banjir dan menyediakan komunikasi yang berkesan ke arah bahaya banjir antara masyarakat dan pihak berkuasa. Metodologi Reka Bentuk Penyelidikan Eksperimen telah diguna pakai untuk mereka bentuk, membangun dan menilai model yang dicadangkan. Kajian ini dimulakan dengan mengkaji prosedur operasi standard semasa pengurusan bencana banjir dan diteruskan dengan mengkaji ciri-ciri data media sosial yang boleh digunakan dalam penyelidikan ini. Statistik inferensi, ANOVA, digunakan untuk menilai dan menganalisis keputusan. Sumbangan utama kajian ini adalah model cadangan yang terdiri daripada empat komponen utama, iaitu amaran krisis, kesedaran banjir, perkhidmatan am dan komunikasi. Dapatan menunjukkan bahawa keempat-empat komponen utama yang dicadangkan dalam model kajian ini adalah berkesan untuk penyepaduan teknologi dalam meningkatkan kesedaran situasi kejadian banjir. Model yang dicadangkan telah disahkan melalui reka bentuk prototaip, yang dinilai melalui penilaian kebolehgunaan. Penemuan mengesahkan bahawa model yang dicadangkan mempunyai nilai min tertinggi untuk ciri Krisis, Kesedaran Banjir, Perkhidmatan Am dan Penggunaan Media Sosial yang bermaksud model tersebut paling banyak dipilih oleh pengguna dan ia menunjukkan model yang dicadangkan mampu menyediakan maklumat yang boleh dipercayai semasa krisis banjir. serta mempertingkatkan kesedaran terhadap situasi kejadian. Penemuan lanjut kajian ini juga mengesahkan bahawa terdapat perbezaan yang signifikan antara komponen dan setiap platform yang dinilai. Penyelidikan ini telah berjaya menunjukkan bahawa meningkatkan kesedaran situasi boleh menjadi salah satu cara untuk mengurangkan kesan krisis banjir dan ia boleh dilakukan dengan mengintegrasikan data media sosial dengan data meteorologi yang mana inisiatif utama adalah untuk memasukkan masyarakat dalam pengurusan bencana. Penyelidikan ini telah berjaya mencapai matlamatnya, iaitu untuk meningkatkan kesedaran situasi krisis banjir dan menyediakan komunikasi yang berkesan ke arah bahaya banjir melalui penggunaan data media sosial yang disepadukan dengan data meteorologi.

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LIST OF ABBREVIATIONS

SOP - Standard Operating Procedure

SM - Social Media

SQL - Structured Query Language

NLP - Natural Language Processing

PSL - Probabilistic Soft Logic

EDM - Event Detection Module

API - Application Programming Interface

NADMA - National Disaster Management Agency

DID - Department of Irrigation and Drainage

NGO - Non-governmental Organisation

PDRM - Polis Diraja Malaysia

MKN - Majlis Keselamatan Negara

ATM - Angkatan Tentera Malaysia

RQ - Research Question

SA - Situational Awareness

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CHAPTER 1

INTRODUCTION

1.1   Overview

The nation has suffered several major floods over the past decade which, according to the World Meteorological Organization (WMO), it remains the third largest natural disaster causing billions of damage and harms. Department of Drainage and Irrigation defining flood as a body of water, swelling, rising and overflowing land. Also, overflow of riverbank, lake, or water drainage application to neighbouring area due to storm, ice melting, tidal activity and blocking of channels.

Flooding is a catastrophic event, which is given extra concern since it compromises the lives, activity and the economy of the citizens. Figure 1.1 shows the statistic of flood events in the world since 1950 and it shows that the Asian countries facing the highest number of flood events. Malaysia is no exception from facing this disaster every year. Malaysia remains vulnerable to flash flooding in certain state due to its complex and enigmatic meteorology, and highly urbanized populace. The latest flood event in Malaysia happen in December 2021 which has caused at least 54 death and 2 missing and affected more than 125,000 people (Astro Awani, 2022). The monsoon and flash floods will continue to cause flooding in these countries, despite the government's extensive structural and non-structural initiatives to mitigate the damage.

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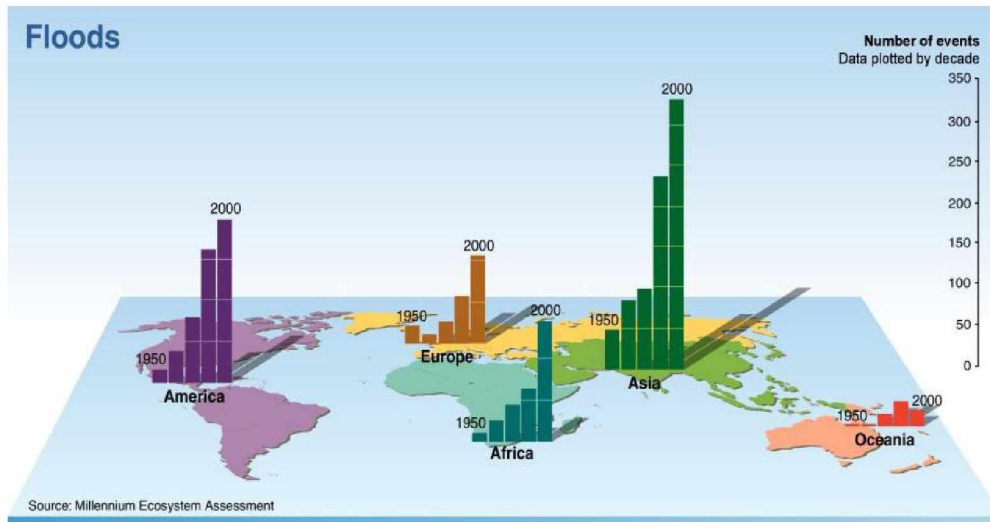
Figure 1.1   Number of floods by continents since 1950 (Philip & Emmanuelle, 2007)

As meteorology have been part of the flood mitigation initiatives ever since before, the data will be helpful to support the analysis of this research. Meteorology is a branch of science that studies the atmosphere, weather, and climate change. Temperature, air pressure, moisture, and wind direction are all monitored and recorded every hour, therefore the monitoring of change in those weather factors normally requires a big database (Ali et al., 2019). The integration of social media data with meteorological data will increase the reliability and accuracy of the information gained. For example, Malaysia has Met API which provided various meteorological data such as climate, weather forecast, earthquake and tsunami. Those data could be beneficial in supporting the analysis of the social media data regarding the situational awareness.

As the world moves toward Smart City technology, which combines information and communication technology with the Internet of Things (IoT) to improve operational efficiency, public information sharing, and government service quality, Malaysian IT experts are working hard to digitalize every operational mechanism, including disaster management (Smart City Definition and Examples, 2021). Apart from services, smart cities offer the provision of safety measures such as monitoring high-crime areas or employing sensors to provide early warning for disasters such as floods, landslides, storms, and droughts. Because most of the labour to establish and maintain a data-driven environment falls outside the scope of local

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governments, the success of a smart city is dependent on the partnership between the public and private sectors.

Several initiatives have been taken to increase the productivity of disaster management (Martínez-Rojas et al., 2018) including flood disaster management and one of it is by using social media to collect information and communicate with the community. Social media platforms are at the core of what is known as the Live Internet, the most complex and rapidly changing section of the internet where users are continually creating their content (Saravanou et al., 2015). Social media will therefore be a strong source of data for event detection and monitoring, because it is a timely indicator of what is happening in the physical world. The big picture is an estimation of the scope of the disaster: area, casualties, and failed structures (Nazer, Xue, Ji & Liu, 2017). Based on quarter one 2019 earnings report from Twitter, there are approximately 14 million active users from worldwide. While the report from According to Facebook, there are 2.41 billion active users in the second quarter of 2019. This shows that these microblogging platforms is widely used and being highly influential and outstanding among community in this world. The conversational features of this microblogging site were gradually developed to encourage user interaction, and the information structuring has radically changed the social dissemination of emergency information, as well as becoming a virtual space where many internet users turn to search for emergency details (Marwick and Boyd, 2011; Murthy, 2013; Panagiotopoulos et al., 2016). It shows that social media has a potential and can be useful for flood detection and emergency response. The increasing of social media user nowadays has motivates researcher to find ways to include it in various of things such as disaster management, business marketing, health awareness and etc. The future generation of systems, according to the researcher, will require an environment that supports planning, prediction, mitigation, detection, monitoring, and crisis management, which will necessitate the integration of systematic data analysis and complete visualization. The risk communication should involve both parties (public and authorities) during emergency event. This is where the social media play its role in communicating risk. The inclusion of social media in disaster management could provide a timely and accurate visualization of sensor data that contribute to the event. It entails a variety of ways for obtaining data, establishing standards, and enforcing or encouraging specific actions to mitigate risks.

In several research, social media has been utilize to improve situational awareness (SA) and disaster management (DM) in events involving natural hazards (Vongkusolkit & Huang, 2020). It could be used to notify emergency managers and officials to specific situations during an incident by monitoring the flow of data from various sources. Monitoring data flows could aid in the development of "situational awareness". The ability to recognize, process, and interpret essential parts of an incident or scenario is known as situational awareness. Real-time information can aid officials in determining where individuals are, assessing victim needs, and alerting residents and first responders to shifting conditions and new threats as a crisis progresses (Lindsay, 2011). Another possible advantage of social media is that it may improve citizens' ability to communicate with government officials. While present emergency communication systems have generally relied on one-way communication—from agencies or organizations to individuals and communities—social media has the potential to change that since information may flow in several directions (known as backchannel communications). Two-way communication aids officials in compiling lists of the dead and injured, as well as contact information for victims' friends and family members.

This research assesses the feasibility to establish a monitoring model with an automatic set of services aimed at linking weather forecasting with information extraction using social media streams. We take as case study the data generated within Facebook, before and during a recent flood in Johor, Malaysia, assessing the dynamics of the data generation process and the extraction of valuable information for the key stakeholders of emergency management: meteorological agencies, who issue weather forecasts and alerts, and first responder, who have to act in the response phase.

In a conclusion, there are several technologies built and initiatives have been taken to overcome the problem arise regarding the flood disaster management. However, there are still some deficiencies that need to be enhanced and follow the Malaysian vision towards Smart City living. Therefore, this research has propose a flood disaster management model that use the features in social media data and integrate it with the meteorological data and visualize it in an analytical dashboard to

enhance the situational awareness of flood crisis and provide an effective communication towards flood hazard.

1.2   Problem Background

According to the Organization for Economic Cooperation and Development, floods cause more than $40 billion in damage each year around the world (Nunez, 2019). Losses in the United States average close to $8 billion each year, with death rates reaching more than 100 persons per year in recent decades. Millions of people have died in China's Yellow River Valley as a result of some of the world's deadliest floods. In 2010, almost a quarter of Pakistan's territory was flooded, affecting 20 million people and causing close to 2,000 fatalities, with estimated economic damages of around US$ 43 billion (Rudari, 2017). A major flood tragedy has caused infrastructure damage in excess of billions and property has also lost a few thousand houses. In Kelantan and Terengganu, floods that occurred in the year 2000 has killed 15 people and caused more than 10,000 people homeless, while in 2006, 18 people lost their lives and more than RM65 million were destroyed (Chan, 2014).

Several existing techniques and flood mitigation initiatives have been undertaken by various agencies, including the construction of flood plains, river channels and levees and pumping station. The most recent development of these initiatives to be implemented is the forecasting warning application to predict flooding instances, such as flood maps, telemetric rainfalls stations and real-time flood forecasting warning applications. Although the existing predictive warning application is capable in addressing some of the problems in the flood emergency management application, there are some issues in terms of ineffective flood forecasting applications, delayed evacuation response, food distribution, search coordination rescue and reaching out to people who need help. Figure 1.2 shows that the article published by Awani News on December 26, 2014 which takes a statement made by Datuk Seri Mustapha Mohamed, Minister of International Trade and Industry at that time. He said that although the preparations in the paper went

smoothly, but when facing of the real situation, there were many obstacles and problems that could not be solved.

Terdapat kelemahan dalam pengurusan bantuan - Mustapa Mohamed

Astro Awani | Disember 26, 2014 08:17 MYT

KUALA KRAI: Menteri Perdagangan Antarabangsa dan Industri, Datuk Seri Mustapa Mohamed mengakui terdapat kelemahan dalam menguruskan bantuan dan penyelamatan mangsa banjir di Kelantan.

Menurutnya biarpun segala persiapan dalam kertas berjalan lancar, namun apabila berdepan dengan situasi sebenar seperti banjir yang melanda Kelantan kali ini, timbul pelbagai rintangan dan masalah yang tidak dapat diatasi.

MUSTAPA: Timbul pelbagai rintangan dan masalah yang tidak dapat diatasi.

Untuk itu Mustapa menjelaskan, perkara ini akan dilihat secara menyeluruh termasuk kelemahan yang ada.

Figure 1.2   News article on weaknesses of flood management (Astro Awani, 2014)

Different countries have different approaches to manage the disaster. But most of them focusing only on the development of the infrastructure and rely on it in most of the time. Figure 1.3 above shows the spreading of the information in the flood management team in Japan which are typically rely on the water level info. On the other hand, the flood management in UK have advanced method in handling the flood disaster which was established in 2007.
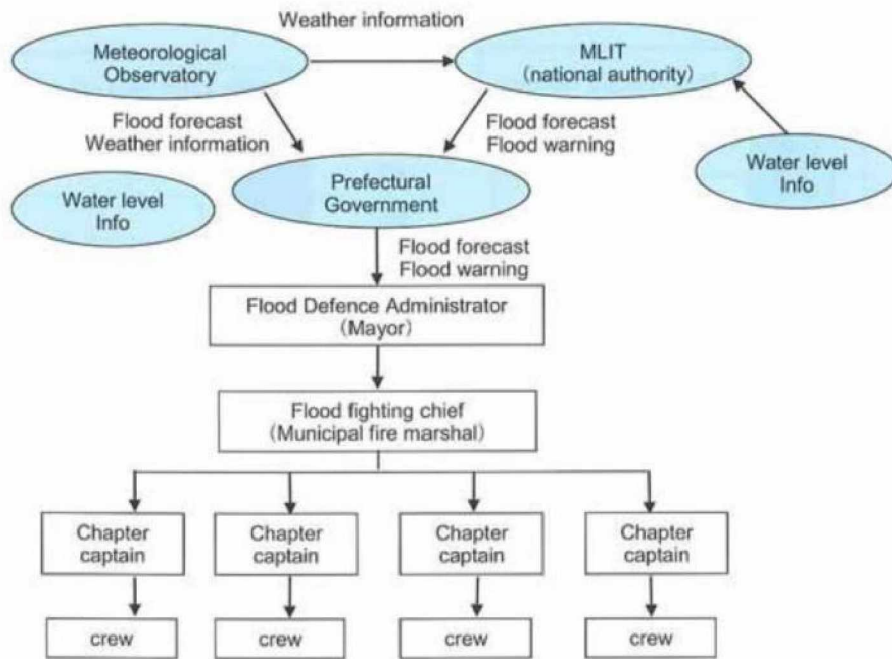
Figure 1.3　　　Progression of flood fighting activities in Japan (Adachi, 2009)

The Environment Agency in UK have introduced the use of social media to send a severe flood warning in December 2013 as shown in Figure 1.4. They use it as the communication channel to warn as the public. However, they found that the efficiency of the crisis and emergency response can only be improved with the involvement of the community. In our global era, the use of social media in disaster response is nothing new. As technology advances, it becomes more popular and widely used to share and acquire information during natural disasters (Aisha et al., 2015; Liu et al., 2015).

FLOOD TECHNOLOGY
Progress made since 2007 summer floods

Huge advances in flood technology mean that we're highly-skilled at not only detecting and forecasting floods but also warning and informing. Here's a look at seven of the reasons why...

Engineering innovations	The Flood Forecasting Centre	Flood warnings direct	Aerial LIDAR (Light detection and ranging)	Social media	ARC boats (Acoustic remote-controlled)	Telemetry
We're using unusual structures, such as self-closing barriers in Cockermouth, Cumbria	We've set up a nerve centre to help us forecast flooding from rivers and the sea	More than 1.2 million people are now registered for our flood warning service	We use aeroplanes to collect data to use in our flood mapping and monitoring	We pioneered the use of Twitter Alerts and use social media to warn and inform during floods	Nimble remote-controlled boats help us monitor river flows and collect river data	Our river level monitoring service covers over 36,000km of rivers in England

*Figures are correct as at June 2017

Sign up for our Flood Warning Direct service online at GOV.UK   or call Floodline on 0345 988 1188   #floodaware

Figure 1.4   Flood progress in UK (Curtin, 2017)

Because traditional sources of communication are unavailable or have restricted access during times of crisis, the community has turned to social media (Aisha et al., 2015). Social media has been utilized in several research to detect natural risks. Earthquake detection and localization have been aided by data from Twitter (Sakaki, Okazaki, & Matsuo, 2010), typhoons (Sakaki, Okazaki & Matsuo, 2010), wildfires (Boulton, Shotton, & Williams, 2016) and heat waves (Kirilenko, Molodtsova, & Stepchenkova, 2015). Social media has various of features that can be implement in the disaster management. The four main features of social media is geo-location (location), network propagation (user), temporal pattern (time) and content. Social media carry a geographic reference which made the platform to be transformed into a location-based social networks whenever the devices is equipped with the Global Positioning Application (GPS) (Albuquerque et al., 2015). Furthermore, it has been demonstrated that the chronological evolution of emergency occurrences and the associated Twitter actions are somewhat synchronous (Wang, Ye, & Tsou, 2016).

Responding quickly and effectively to natural or man-made disasters can reduce fatalities and injuries, control or avoid secondary disasters, and reduce economic losses and social disturbance. Responding organization face significant uncertainty when making key decisions during a crisis. They must collect situational data (e.g., the state of the civil, transit, and information infrastructures) as well as data on available resources (e.g., medical facilities, rescue and law enforcement

units). There is a close link between the quality of decision makers' decisions and the correctness, timeliness, and reliability of the information available to them. Improves in the speed and accuracy with which information about a crisis is transmitted through disaster response networks have the potential to revolutionist crisis response, saving lives and property (Ashish et al., 2008).

In recent years, social media has risen to prominence as a vital source of information and speedy communication in emergency circumstances where news organization have been unable to provide timely coverage owing to a lack of reporters (Ahmad et al., 2018). Disaster-related messages shared on social media have been analyzed to see how people increase their situational awareness by relying on information shared by others (Vieweg et al., 2010; Albuquerque et al., 2015). In emergency situations, situational awareness is strongly linked to space and time. During an emergency, social media and smartphone apps are powerful and effective crowd-sourcing tools for gathering data from multiple sources, collaborating, and disseminating the processed information (Selamat et al., 2018). Social media users who are geographically close to the events are more likely to contribute meaningful information for boosting situational awareness, according to existing studies (Wang, Ye, & Tsou, 2016). Messages posted by Twitter users vary with the temporal process of a disaster, according to Huang and Xiao (2015), and so could provide useful information for boosting situational awareness at various stages of a disaster i.e., preparedness, response, impact, and recovery. The increasing use of Twitter and Facebook in both ordinary and emergency situations indicates their potential contribution to situational awareness and status reports, both of which have proven difficult in mass casualty crises (Cassa, Chunara, Mandl, & Brownstein, 2013). In comparison to traditional media (TV, radio, and newspapers), social media offers a number of distinct advantages that can be leveraged to improve situational awareness and crisis management. Because they play a key part in the rapid transmission of information in the event of a disaster, social media can be categorized as a vital source of information during disaster events to increase situational awareness and disaster management. In catastrophe situations, situational awareness is strongly reliant on the availability, accuracy, and timeliness of information that may be made available to the decision maker.

The citizens also play vital roles in assisting the emergency response and rehabilitation of the people affected. Nowadays, social media platform is one of the most used platforms to spread news in real-time. Platform like Twitter and Facebook being used tremendously by user of different range of ages. In the event of an emergency, social media has produced far more open and ubiquitous information flows between authorities and the public, meaning that social media deserves more attention (Turoff et al., 2013; Panagiotopoulos et al., 2016). The citizens are usually the first on the scene when a flood strike. Insightful information such as locations that need food, medical supplies, or blankets are the one that can be gained from social media data (Nazer et al., 2017; Palen & Anderson, 2016) that were updated by citizens. An important challenge of working with social media data is the tremendously high volume of post generated. Due to the large volume of data typically generated during a crisis, it is impractically to analyse it manually.

1.3   Problem Statement

The government has been criticized over it delayed responses and apathy towards the disaster during the latest flood event. The current disaster management model is relying on meteorological data and traditional emergency alert which has delay them in taking action. The people are seeking for help through their social media as they can not reach to the authorities. The government and other participating entities should have had a better prevention, protection, mitigation and response operations, but the devastating results of the crisis showed that there is a major defect in the current used system and management model. The lack of preparedness to such unexpected event, compiled with the absence of expertise in facing such hazards, and deficiency in reaching and informing the public along with the lack of cohesion between the different entities was the result that magnified the flood crisis.

In the context of disaster management in Malaysia, the usage of social media in crisis management is still relatively low. Thus, it contributes to the lack of exposures to the benefits of situational awareness element that can be gain through

social media data. Therefore, this research has propose a model that use the features in social media data and integrate it with the meteorological data to enhance the situational awareness of flood crisis and provide an effective communication towards flood hazard.

1.4   Research Aims

The aims of this research is to enhance the situational awareness of flood crisis and provide an effective communication towards flood hazard through a model of integrated data from social media and meteorological.

1.5   Research Question

a)   What are the the current flood disaster management model applied in Malaysia and how does the integration of social media data with meteorological data in the disaster management model could enhance the situational awareness of the flood disaster?

b)   How to integrate social media data and meteorological data to for flood crisis event?

c)   Does the result of this study able to improve the effectiveness of the situational awareness of the flood crisis?

1.6   Research Objectives

This research purpose is to gather information and situational awareness during flood crisis for effective disaster relief efforts by using social media analytic. Thus, the objectives of this research are:

a) To investigate the current model of flood disaster management and analyse the features of the integrated data from social media data and meteorological data in providing situational awareness of flood disaster.

b) To propose a model of integrating the social media data and meteorological data for flood crisis event.

c) To evaluate the effectiveness of proposed flood disaster management model based on the situational awareness.

1.7 Scope

This research is taking the sample from Johor state as Johor is also one of the state that facing the flood disaster every year. Facebook is chosen to be the social media data provider which is based on public stream. This is because the Facebook database and API is more accessible compared to other social media such as Twitter and Instagram. The data fetched can be easily classified and filtered accordingly.

1.8 Research Significance

Crises and situation of natural disaster and mass emergency such as flooding, earthquakes and hurricane have causes massive damage to live and property. This research has compiled all of the idea and perspective to built a mechanism and machinery to improve the disaster management efficiency. This study has shows that the proposed model have enhanced the situational awareness in the perspective of providing the related information. Towards achieving the aims of this research, these are part of the study contribution and significance:

● This research output is a model and task for citizen and disaster response to mitigate the impact of a crisis. The model involving the participation from both parties which is authorities and community that will help in providing immediate

action to help the victims and also providing the information of the real situation during the disaster.

- As social media has been a main medium that spread the news and information of a disaster in real time, this study could help a disaster analyst to collaboratively accumulate post associated with crisis and analyze it through the use of visible analytic to become aware of regions, topics, reliable content material and users involved which could be useful in disaster management to mitigate the impact of the crisis.

- It leverages the power of crowd sourcing knowledge through the implementation of the machine learning in social media and propose a novel/new way to forecast and generate flood alerts and situational awareness for citizen based on the integration of a social approach and meteorological features.

- This proposed model also can help citizen and government to recognize and understanding user behavior patterns during natural disaster crisis.

1.9   Thesis Organization

The structure of the thesis will be organized as follows:

Chapter 1: A detail overview of the research which covers problems, objective and aims.

Chapter 2: The outlining of the project background by conducting the literature review in the chosen topics which is flood disaster, flood disaster management, social media analytic, situational awareness, meteorological data and discussion on the related previous work. This chapter also will cover the research question arise with the objective is to identify the current model of flood disaster management in Malaysia and also the features of social media that suitable for situational awareness.

Chapter 3: Covers the method on how to implement the research. The theoretical research model is generated in this chapter to give a brief overview on each phase to conduct the research. There are four phases generated: research analysis, data acquisition, implementation and analysis and evaluation. Every step taken on each phase is explained thoroughly.

Chapter 4: This chapter explained on the proposed model architecture. The integration part is shown in a graphical way and explained thoroughly. All the data used, technical part, programming language and system architecture is explained in this chapter.

Chapter 5: The analysis is covered in this chapter. The information gathered during the usability testing is subsequently analyzed with the SPSS software. Quantitative analysis is conducted with the one-way repeated measures of ANOVA are used. At the end of this topic, all of the data will be thoroughly reviewed in order to arrive at a relevant conclusion.

Chapter 6: This chapter gives the overall conclusion of the research study done. The suggestion for future work is explained in this chapter which gives the idea of implementing this research into an actual development that could be used in the future during the flood disaster event.

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