Near Real Time Wildfire Monitoring in Chiang Rai Province using Mobile Phone Application

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Abstract

The authors of this paper present a newly developed mobile application based on mobile phone's Android operating system to monitor the wild fire occurrences in Chiang Rai province in near real time.The main components of the application are fire mapping, statistical displaying and emergency calling capability. The main data used in this applicationare active fire pixels or fire hotspotswhich are daily downloaded from Fire Information for Resource Management System(FIRMS) server operated by the Earth Science Data and Information System (ESDIS) of the National Aeronautics and Space Administration (NASA) to local GIS server in Far Eastern University in Chiang Mai, Thailand. The downloaded data were filtered to have the active fire pixels geographically located within Chiang Rai province, classified by districts and sub-districts. Then, the mobile application will fetch the filtered data in every 5 minutes daily from the server to display the fire hotspot distributionusing hybrid Google map background, show statistical analysis and give warning to the mobile phone users.This application also has capability to calculate the distance from the user location to fire location as straight-line and along road paths.This application provides the possibilities to the fire fighters to work effectively. It support them to extinguish the fire in shorter time and safely. This application was introduced to the local provincial government organisation which has provided positive response and full support to apply it in the local community in district and sub-district levels in Chiang Rai province, which is very helpful to reduce the loss of the environment and air pollution due to wild fire.

Keyword: Active Fire Pixels, Fire Hotspots, MODIS, Near Real Time, Android Operating System.

1. Introduction

Smoke pollutionproblem occurs annually in Northern Thailand during January to April. The problem gets worse in March yearly. The main reason is due to wild fire which occurs in national park and also in open burning areas related to agriculturalareas by human activities. Chiang Rai is considered as one of the top risk burning areas in Thailand due to the preparation of farmland for rice and corn cultivation which cover approximately 35.40 % of the total land [1]. Moreover, Chiang Rai province shared the borders with Myanmar and Laos forest areas, in which high number of hotspots are located in these neighbouring countries. Based on PM10 reports from ground measurement station T73 located in Mae Sai sub-district, the measured average PM10 levels in February, March, and April in 2009 to 2012 is more than standard [2]. On March, PM10 level reaches 270 µg/m3. As a result, local people suffer from smoke haze problem and travelling business is dropped.

Since the availability of NASA MODIS fire product MOD14/MYD14 developed using the fire and thermal anomalies algorithm since 2001 until present [3] for the global coverage, many researches related to wildfire or forest fire monitoring using MODIS fire products were carried on in many places of the world where wildfire occurs [4]. Hawbaker T. J., et al [5] has evaluated the NASA daily MODIS product to quantify the rate of detection to understand how cloud cover and fire size influenced to the detection capability

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of the MODIS sensors on board of Terra and Aqua satellites in the United States.MODIS fire product was used in research work conducted by Tansey et al [6] in Central Kalimantan, Indonesia to study the relationship between MODIS fire hot spot count and burned area in a degraded tropical peat swamp forest.Another research on forest fire detection was conducted by Manyangadze [7] to apply different geostationary satellites for forest fire detection in near real-time in Portugal and Southern part of Africa.In Thailand, several research related to wildfire monitoring in Chiang Rai were carried on using MODIS fire product to monitor and analyse the spatial distribution of the active fire hotspots and its relationship to the particulate matter 10 micrometers or PM10 concentration in the province [8]. However, these researches can only give a scenario of the wildfire phenomenon in the province, but still cannot apply to manage the wildfire efficiently as it is still not easy to disseminate the active fire hotspots information detected daily by MODIS to fire fighters toextinguish the fire in short time.The hotspots information was reported twice a day in the morning and afternoon after the overpasses of Terra and Aqua, respectively to fire fighters at the Conservation Area Management Bureau (CAMB) 15 of Chiang Rai province. After that, fire fighters take this report to organize working plan for controlling burning area. However, this working process spent at least 4 hrs because they need to wait for the updated hotspot information which comes from the only single source. Moreover, it is difficult to organize a working plan to control burning area due to insufficient spatial information. Also, inaccurate information due to false detection related to high temperature house roofs which interpreted as hotspots cause difficulties in the implementation of the wild fire protection.Therefore, it is necessary to develop a new tool to support quick and accurate fire information dissemination and provide more guarantee to the fire extinguishing effectively. This is the idea how the mobile application on mobile phone was initiated.

Since nowadays mobile phones are widely used in our daily life. Various mobile applications or apps were developed for different purposes. Several developers have developed apps for wildfire detection and mapping. Some examples can be listed here. The Advanced Fire Monitoring System (AFIS) was developed by the South African developers as a satellite-based fire information tool which provides fire information in near real-time to users [9]. Alberta's Wildfire is another application that provides up-to-date wildfire information with mapping feature for Alberta in Canada [10]. Google maps-based application Firepoint also wasdeveloped to support tracking of fires world-wide with updated information on current outbreaks of fire [11]. In Portugal, a mobile application named Fogos.pt was developed to monitor fire in the country in real time mode [12].Another application developed by Portugal namedIncêndios Florestais or "Forest Fire" in Portuguese, which geographical information of forest fires in Portugal and Brazil [13]. Another application developed for identifying the area to be on the risk of forest fire in Thailand is developed by Geo-Informatics and Space Technology Development Agency (GISTDA) of Thailand [14]. We have seen many mobile applications for monitoring and mapping wildfire, but all of them can't provide adequate fire information for Thailand, in particularly Chiang Rai province where is the area of our interest and one of the provinces with high number of wildfire in the country. Based on this, the authors of this paper have initiated the need of having a mobile application to monitor wildfire in Chiang Rai province and to support the local fire fighters for better fire management.

In this paper, a new mobile application on mobile phones was proposed and implement to the development. This application consists of 3 main parts which are active fire mapping, statistical analysis and emergency calling.

The structure of the paper is organized with the following sections: In the study area and used data, we introduced the study area which is Chiang Rai province as it is one of the most affected provinces by the wildfire and smog problem in Thailand. The data used in this research was described. Next, in the methodology section, we discussed about the flowchart and the design of the application. Finally, in the result section, the implementation of the application and the spatial distribution of the hotspot with several attribute comparing with the ground data obtained from the field survey were described. Finally, the conclusion presents the work summary and further work.

2. Study area

The study area in this study is Chiang Rai province, located in the Northern part of Thailand. This province has the geographic coordinates at the latitude of 19.00o N to 20.50o N and longitude of 99.25oE to 100.75oE covering 18 districts, 124 sub-districts, and 1,751 villages.

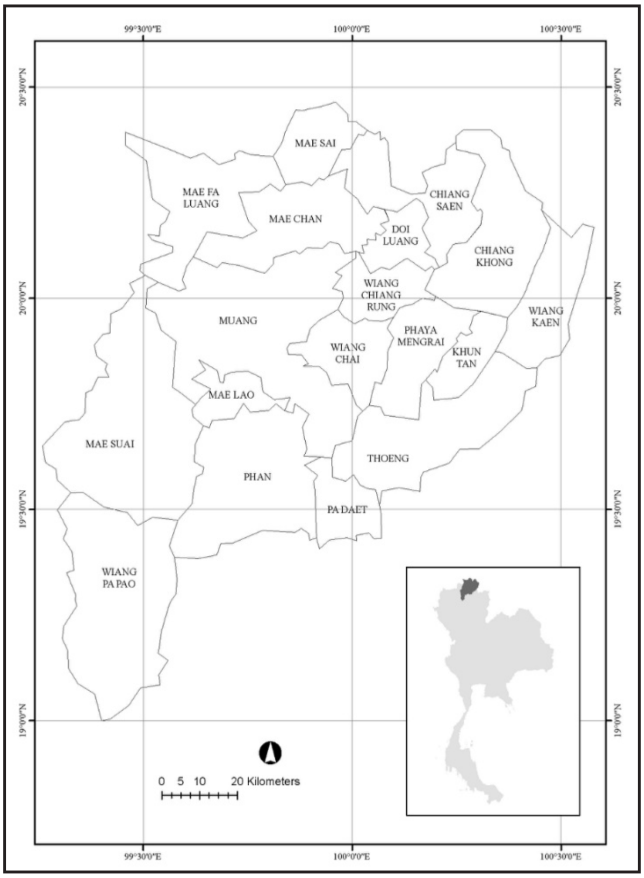

Figure 1. Administrative boundary of Chiang Rai province.

3. Used data

The active fire data used in this research project is MODIS Fire Product, obtained from FIRMS website of NASA which is generated using the MODIS data acquired from Terra and Aqua. These two satellites have a revisit time of 1 to 2 days which is one of the advantages of using the MODIS data acquired by these satellites during day and night time [15]. The near real time active fire data processing is generated by MODIS Adaptive Processing System (MODAPS).

3.1 Application of MODIS Data for wildfire monitoring

Since the launch of Terra and Aqua satellites for earth observation mission in 1999 and 2002, respectively, MODIS sensors onboard of the two satellites have greatly provided numerous products for global earth environment and disaster management. One of the products is MODIS fire product. MODIS fire product from Terra (MOD14) and Aqua (MYD14) are level 2 products, which were generated from MODIS level1-B using the MODIS fire detection algorithm by NASA (Algorithm Technical Background Document (ATBD) MOD-14) and available for free downloading at the NASA's Fire Information for Resource Management System (FIRMS) at the link https://earthdata.nasa.gov/earth-observation-data/near-real-time/firms. The MODIS fire product consists of many physical parameters, including latitude, longitude, 4-μm brightness temperature at thermal band 21 (T4) , scan, and track number, acquisition date, acquisition time, satellite name, fire detection confidence, production version, 11-μm brightness temperature at thermal band 31 (T11), fire power and day night flag. For our application, only latitude, longitude and fire confidence of the fire pixels are used.

3.2 MODIS fire detection confidence

The fire confidence is a parameter that provides the information of the detected fire pixel related to the possibility of a potential fire or false alarms as clear, non-fire and land pixels.

The fire confidence class assigned to a fire pixel is defined by thresholding the confidence value (C) calculated for the fire pixel (Louis Giglio, 2010).

The confidence (C) of a fire pixel detected by MODIS is calculated as a heuristic measure of the geometric mean of five sub-confidence parameters, defined as C_1 through C_5. (Louis Giglio et al, 2016) These parameters are defined in terms of 4-μm brightness temperatureT_4, the number of adjacent water pixels (N_{aw}), the number of adjacent cloud pixels (N_{ac}),the standardized variables $Z_4 = (T_4 - \overline{T}_4)/\delta_4$ and

$Z_{\Delta T} = (\Delta T - \overline{\Delta T})/\delta_{\Delta T}$ and the ramp function $S(x; \alpha, \beta)$, defined as in equations 1 – 3 below:

$$if\ x \leq \alpha\ ;\ then\ S(x;\ \alpha,\ \beta) = 0; \tag{1}$$

$$if\ \alpha < x < \beta,\ then\ S(x;\ \alpha,\ \beta) = \frac{(x - \alpha)}{(\beta - \alpha)}; \tag{2}$$

$$if\ x \geq \beta,\ then\ S(x;\ \alpha,\ \beta) = 1 \tag{3}$$

And the five sub-confidence parameters are calculated as shown in the equations 4 - 8 below:

$$C_1 = S(T_4;\ T_4^*;\ 360K) \tag{4}$$

$$C_2 = S(Z_4\ ;\ 3.0,\ 6) \tag{5}$$

$$C_3 = S(Z_{\Delta T};\ 3.5,\ 6) \tag{6}$$

$$C_4 = 1 - S(N_{ac}\ ;\ 0,\ 4) \tag{7}$$

$$C_5 = 1 - S(N_{aw}\ ;\ 0,\ 4) \tag{8}$$

The confidence range is classified as low ($0\% \leq C < 30\%$), nominal ($30\% \leq C < 80\%$) and high ($80\% \leq C \leq 100\%$).

4. Methodology

The development of the mobile application can be briefly described in the following steps, as it is illustrated in Figure 2 below:

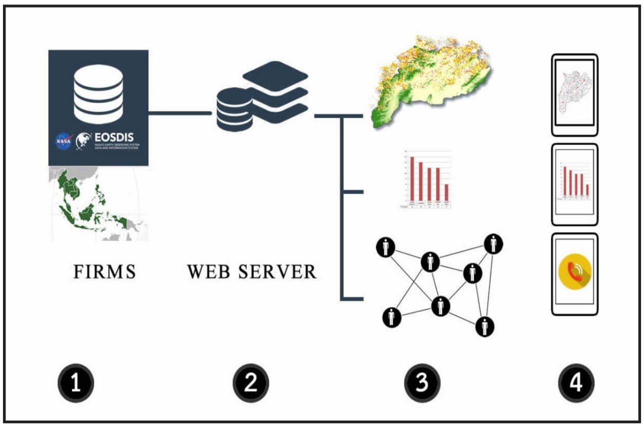

Figure 2. *Framework of the mobile application development.*

At first, daily active fire datasets of Southeast Asian region was scheduled to automatically download in every 5 minutes from NASA's Fire Information for Resource Management System (FIRMS) at the link https://earthdata.nasa.gov/earth-observation-data/near-real-time/firms by thelocal computer web server located at Far Eastern University, Chiang Mai province, Thailand.Secondly, the active fire data from FIRMS comprise various parameters as listed in Section 3.1 are allocated in local web server. Only the datasets related to Chiang Rai province will be extracted using automatic filter system for further use. Thirdly, the automatic filter system on the web server matches fire hotspots location with Google Map and convert latitude and longitude to UTM coordinates system which is compatible for GPS navigation. In matching process, the firehotspots location is calculated using the administrative boundary of district (or Amphoe in Thai) and sub-district (or Tambon in Thai) levels to estimate the geographic location of fire hotspots. Lastly, the filtered fire hotspots data for Chiang Rai will be display on the map using Google Map as background to facilitate the mapping capability to be more informative. Simple statistical analysis of the daily fire hotspots detection is also available for reports. Another feature is the application has the capability to make an emergency call to the local authority for the preparation in case of wildfire occurrence.

The mobile application illustrated in Figure 3 provides the information on the spatial distribution of the fire hotspotswith several spatial attribute related to sub-district, district and province names, fire hotspotsacquisition time and date by satellite, geographic coordinates, fire confidence, and satellite name. The fire hotspotgeographic location is calculated using Spatial Join Analysis as one of GIS techniques. This technique joins attributes from one feature to another based on the spatial relationship. The target features and the joined attributes from the join features are written to the output feature class which connects with FIRMS.

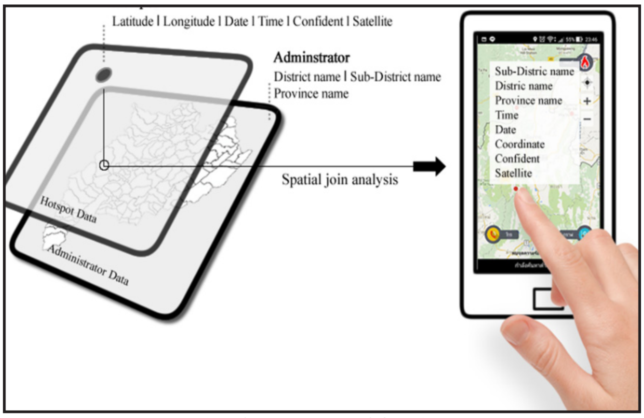

Figure 3. *Spatial information of fire hotspots on mobile application.*

5. Results and discussions

We have conducted data validation for 15 detected hotspots displayed on our mobile application with the fire data collected from the field survey, provided by CAMB 15. We found that, most of detected hotspots by our mobile application are well matched with the fire data collected from the ground, only few hotspots are not fire, but heat emission from house roofs, which are considered as false detection and can be easily eliminated using the fire detection confidence, developed by NASA's Fire Product Algorithm Team. This parameter is very effective to identify the fire detection reliability and to eliminate non-fire or fire false detection, even though the detected fire pixel has the size of 1 km by 1 km, with this parameter and the capability of the experience fire fighters, accessing to the fire area is made possible and efficient.

Figure 4. *Practical use of the mobile application navigator function in the field survey.*

Figure 4 shows an example of the practical use of the mobile application in the field survey. On March 5, 2016 at 13:45, fire hotspots were found at the coordinates of UTM 541681 E, 2146131 N which is located in forest area of Sunlee sub-district, Wiengpapao district. The mobile application alerts fire hotspots on smart phones of fire fighter at CAMB 15 and help them to plan for controlling the occurred fire. Figure 5 shows the capabilities of the mobile application to be able to navigate to the fire hotspots location, by calculating the distance from the current location of the user to the fire hotspots location. This is very helpful to assist the fire fighter to allocate the fire location efficiently.

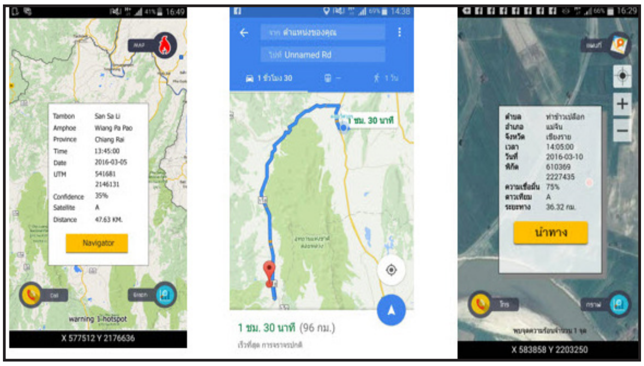

Figure 5. *Practical use of mobile application navigator function in the field survey to allocate the fire hotspots location.*

The functionality of the mobile application can be explained that, hotspot data fetching from FIRMS by the local server at Far Eastern University is functioning every 10 minutes, and the mobile application fetch from the local server every 5 minutes. Therefore, within every 10 and 5 minutes the local and mobile systems is keeping automatically updating the data using the data from FIRMS. This can be ensured to cover all of the hotspots detected by MODIS and generated by FIRMS. Comparing with the fire data dissimilation by GISTDA by e-mail to users by GISTDA officers, our application performance may be slower, but the advantage is, it performs automatically which is cost saving solution and guarantee the data distribution efficiently.

According to practical use of the mobile application during the field survey in Chiang Rai province with 5 fire fighters including the team leader and his four members, the satisfaction of these users are shown in the Table below.

Table 4. *Users Satisfactions in the use of the mobile application.*

Description	Level of Satisfaction (0 – Low, 5 - High)	Remarks
Easy to use	4.00	Simple and easy to use. Selection of the destination and navigation
Data speed and accuracy	3.80	Data distribution is sometimes slower than from GISTDA, but the advantage is, it performs automatically.
Efficiency comparing with traditional working style	4.00	Solution for the fire fighters. Geographic locations are applicable with the GPS coordinates of the fire fighters.
Overall satisfaction	4.40	

6. Conclusions

Chiang Rai Hotspot Application is a geospatial mobile application based on Android OS which displays the location of the wildfire in term of fire hotspot. The fire hotspotsgeographic allocation and display on Google Map with geographic coordinates including UTM and latitude / longitude was developed. The warning system which has connection to the incoming fire data from FIRMS is included. Statisticalanalysis for displaying the top five highest numbers of fire hotspots in a day is also developed.

With connection to data downloading from FIRMS, the system of the application keep updating the data every 5 minutes to ensure the data on mobile phone to be up-to-date. Theautomatic notification system of the application, including statistical graphs of district or sub-district and detailed geographic coordinates of each fire hotspot point with a navigation system is able to providefresh informationto support the community networks for preventing and wildfire and smoke haze problem and be able to safely extinguish the fire in Chiang Rai efficiently.

The performance of the application was tested in the period of March 01-31, 2016 which is a very common wildfire season over a year. It is used as a tool to track and allocate the fire hotspotslocation. Moreover, it can contribute to the awareness of officers, in particularly, fire fighter and related government agencies. It leads to the establishment of a network of anti-smoke haze problem and the fire hotspotsinformation of Chiang Rai Hotspot Application is linked in the social network LINE groups of staff. In a joint reportof fire hotspots, the implementation of the authorities can control the situation in all sectors to resolve the smoke haze. As a result, the networks of Chiang Rai province are committed to resolve the problems of wildfires and smoke haze problem concretely.

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