DEVELOPMENT PROGRAM NEAR-REAL TIME RAINFALL ESTIMATION USING AUTOMATIC PICTURE TRANSMISSION IMAGE FROM NOAA SATELLITES

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ABSTRACT: This article proposes a development of near-real time rainfall estimation program using Automation Picture Transmission (APT) image received from inexpensive APT reception system with relative humidity and air pressure from the METAR reports. The developed program can be applied to forecast rainfall in the short term for planning, preparing and taking action to timely prevent the disasters by rain.

A near-real time rainfall estimate program developed by Python language. A program can estimate the position of rainfall / No rainfall and quantity of rainfall. The position of rainfall / No rainfall estimation model used the gray scale value of APT images obtained from the Advance Very High Resolution Radiometer (AVHRR) channels 2 and 4 with relative humidity and air pressure from the METAR reports at 11 airport stations around of Thailand. The quantity of rainfall model used the relationship between the gray scale value of the APT image from the AVHRR channels 2 and 4 with rainfall value from the rain measurement stations. This equation can expressed as $Rain\ rate = -7.046 + (0.046 * GS_2) + (0.046 * GS_4) - 0.539$, the unit in millimeters per 15 minutes (mm./ 15 minutes). When GS_2 and GS_4 are the gray scale values of the APT image from the AVHRR channels 2 and 4, respectively were 0 to 255.

The near-real time rainfall estimate program tested with APT images and METAR reports during June to August 2010, found that the position of rainfall / No rainfall estimation error were approximately 10.21% and quantity of rainfall error were approximately ± 0.289 mm./15 minutes. The near-real time rainfall estimate program can be applied to the normal rainfall in rainy season. It can not be applied to the rain in monsoon storm and estimation in the daytime only.

INTRODUCTION

The climate change impacts natural disasters in many regions around the world. In last year, Thailand had been affected by climate change, causing heavy rain in many areas across the country. Many people have been damaged for life and properties. The Thai Government, such as the Royal Irrigation Department, Department of Water Resources, Department of Disaster Prevention and Mitigation and The Local Administration request real time or near-real time rainfall data cover the country for monitoring, forecasting, estimating rainfall and using in managing, planning, protecting and assisting the people affected by floods. Thus, the satellite receiving system, rainfall estimation program and continuous data will solve the flood problem. The Automatic Picture Transmission (APT) images from NOAA satellites were selected for this study because the APT receiving system is inexpensive and easy for installation.

The APT system is analog transmission of data stream from the Advance Very High Resolution Radiometer (AVHRR) instrument on NOAA satellites. It transmits the data continuously broadcasted in form of radio wave with 137 MHz frequency band. The APT image consists of two *4* km/pixel low resolution images derived from two channels of the AVHRR, one is typically thermal infrared *(10.8* micrometers*)* with the second switching between near infrared (*0.86* micrometers) and mid infrared (*3.75* micrometers) depending on day or night time of the satellite orbit. However, the NOAA ground control stations can configure the satellite to transmit any two of the AVHRR channels. The user station anywhere in the world can directly received in real time local data by simple and inexpensive ground receiving system (Chonmapat, 2008). At the present, the user can receive APT data from each satellite (NOAA15, NOAA17, NOAA18 and NOAA19) (NOAA, 2011), twice a day.

The infrared and thermal infrared images from satellites are the most useful in providing information on the spatial distribution of cloud, cloud brightness, cloud top temperatures and cloud areas, which are the parameters used to calculate the rainfall. The researchers are using satellite images with ground data for rainfall analysis, for example. (Inoue and Aonashi, 2000) compared cloud information from TRMM VIRS with rain measurements from the Precipitation Radar (PR) for rain cases during June 1998 over a frontal zone in East Asia. (Hsu, et al., 2002) used GOES satellite data to estimate rainfall at Las Vegus. The method used relationship of cold cloud top temperature and rainfall at a pixel resolution of 0.04° x 0.04°. (Billa, et al., 2004) researched quantitative precipitation forecasting using cloud-based techniques on AVHRR data for flood warning system at Langat river basin, Malaysia. They used channel 1, 2 and 4 of AVHRR data to classify five classes of features representing the land, sea, low stratus cloud, mid altos cloud, high cirrus cloud while threshold cold cloud temperature below 235K was taken as the indicator of rain and (Saisunee, 2004) studied rainfall estimation for flood management of Pasak river basin in Thailand. In this study, rainfall estimate was initially accomplished by computing the power-law regression relationship between cloud top temperature in infrared band of GMS-5 satellite and observed rainfall rate at the synoptic station.

STUDY AREA

The study area is located between latitude at 4° 54’ 36.00” to 20° 52’ 12.00” N and Longitude at 97° 00’ 0.00” to 105° 58’ 12.00” E, which covers all areas of Thailand and neighboring areas. There are approximately 1.6 million square kilometers. As shown in Figure 1.

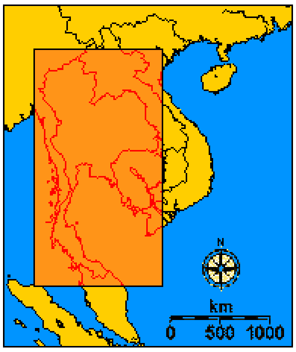

Figure 1. The study area.

DATA AND TOOLS

The data and tools used to develop near-real time rainfall estimation program as follows:

1. APT image from my APT receiving system installed at 13° 51’ 14.03” N and 100° 36’ 28.28” E in Bangkok (Chonmapat, 2007).
2. Relative Humidity (RH) and Air pressure (P) from METAR report, which can be downloaded from internet.
3. Rainfall data from rainfall measurement stations of the Department of Drainage and Sewerage, Bangkok Metropolitan.
4. WxtoImg software for decode APT image.
5. MetarWeather software for decoding METAR report.
6. Python software for developing near-real time rainfall estimate program.

METHODOLOGY

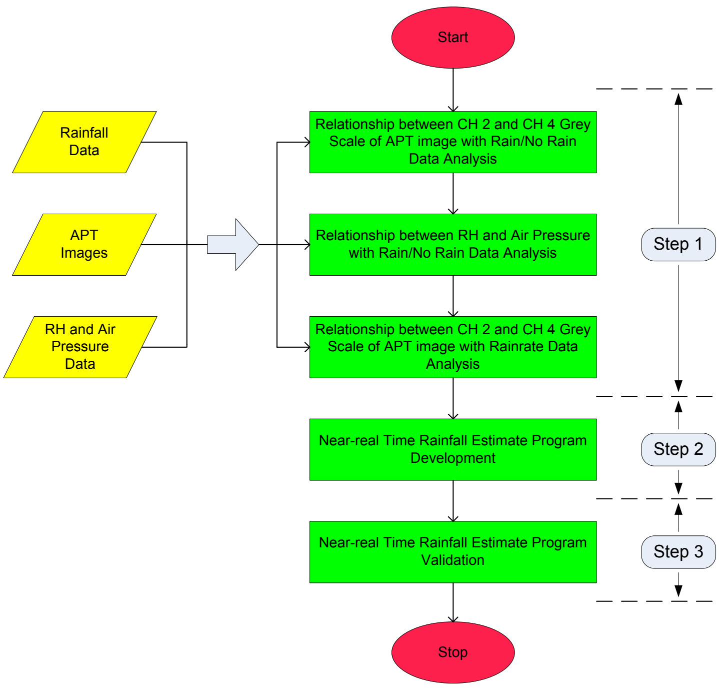

Figure 2. Research processes diagram.

Basically, the processes of near-real time rainfall estimation program development are shown in Figure 2.

In step 1, the climatic analysis for raining conditions is the process to the positions which have the opportunity to rain. The 4 parameters, CH_2 and CH_4 gray scale of APT image, RH, P values and rain/no rain data from METAR report of 11 airport stations around of Thailand with temporal corresponding to selected APT image were used in this step. Select 9 APT images in June-October 2006 while the rain, 79 datasets used for this analysis. The results are as follows:

1.1 The CH_2 and CH_4 gray scale of APT image related with raining have 105-239 gray scale value of CH_2 with 225-255 gray scale value of CH_4 and 105-149 gray scale value of CH_2 with 135-224 gray scale value of CH_4 as shown in Figure 3.

Grey scale of CH4

Grey scale of CH4 \ Grey scale of CH2	75-89	90-104	105-119	120-134	135-149	150-164	165-179	180-194	195-209	210-224	225-239	240-255
240-255			3	10	7	6	6	2	1	3	3	1
225-239				1	5	3	1		1	1	1	
210-224			2	3	2							
195-209												
180-194			1	1								
165-179			1	2	2							
150-164			1	4	1	1						
135-149		1		1	1							
120-134												
105-119												
90-104												
75-89												

Figure 3. The table of relationship between CH_2 and CH_4 grey scale of APT image with raining.

1.2 The RH and P related to the raining conditions were plotted as shown in figure 4. RH can be categorized into 3 groups, RH 80-100% for 95% possibility to raining, RH 60-80% for some possibility to raining and RH < 60% for 100% possibility to no raining. The P > 1006 mb for 100% possibility to no raining.

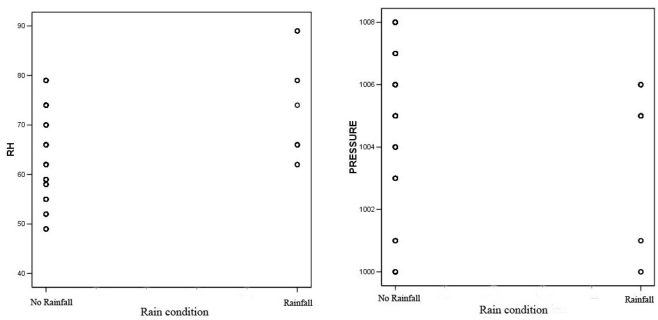

Figure 4. The graph of relationship between RH, P and Rainfall/No rainfall.

1.3 For rain rate equation analysis used gray scale of CH_2 and CH_4 of APT image with rain rate data of events having probability of raining by regression model. The equation can expressed as Rain rate = -7.046 + (0.046 * GS_2) + (0.046 * GS_4), the unit in millimeters per 15 minutes (mm./ 15 minutes). When GS_2 and GS_4 are the gray scale value of the APT image from the AVHRR channels 2 and 4, respectively were 0 to 255, which R^2 is 0.622.

In step 2, Near-real time rainfall estimation program development. The results of raining conditions and rain rate regression model, from step 1, were developed by Python language. The program development will allow input data in APT images both CH_2 and CH_4 covering the study area, RH and P data from 11 airport stations in .dbf format. The output data are rain map display and rain rate of the point data in .dbf format. The operation steps of the program can be displayed as flow diagram in Figure 5.

In step 3, Near-real time rainfall estimation program validation. The selected APT images in June-August 2010 were processed and employed to validate results from the rainfall estimation program development.

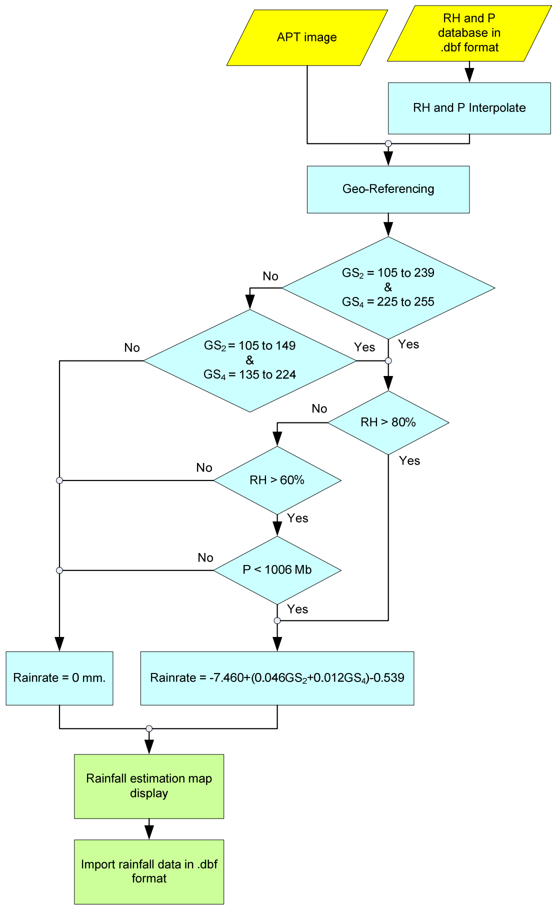

Figure 5. Near-real time rainfall estimation program process flow diagram.

The input data of near-real time rainfall estimation program consists of 2 APT images (CH_2 and CH_4) and RH, P data in .dbf file format. The first step of program process, interpolated RH and P point data set to raster format as same as APT images and geo-reference. Then, check gray value of the APT images, RH and P in same pixel position, which have the opportunity of raining as according to the climate condition analysis. The pixels which are likely to raining will be instead the gray values of CH_2 and CH_4 APT images in the rain rate equation but the pixels which represent no rainfall will be replaced with 0 mm. The output displayed rainfall map and generated rain rate database. Near-real time rainfall estimation program developed is shown in Figure 6.

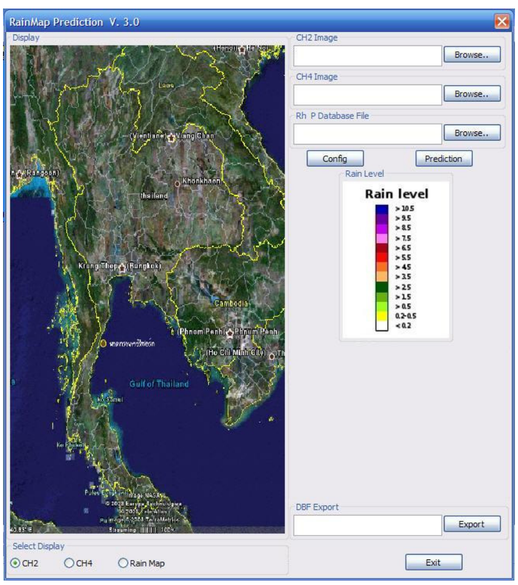

Figure 6. Near-real time rainfall estimation program developed by Python.

RESULTS

The principle of near-real time rainfall estimation program design is to combine raining condition analysis and the regression equation for rain rate estimation together. This was developed to be the program using Python language. The rain rate values on map output is displayed by color scales which are in the unit of mm/15 minutes, as shown in Figure 7. The output rain rate table database consists of point location in Latitude, Longitude, X, Y of each pixel and rain rate data in .dbf file format are shown in Figure 8. The output data can be further generated to be GIS layer of grid point data with attributes of rain rate estimated from regression equation.

The near-real time rainfall estimation program tested with APT images and METAR reports during June to August 2010. To test the developed near-real time rainfall program is to take the results from the program to compare with the rainfall values measured from 71 rainfall measurement stations of the Department of Drainage and Sewerage, Bangkok Metropolitan covering Bangkok area. The tested results found that the position of rainfall / No rainfall estimation error were approximately 10.21% and quantity of rainfall error were approximately ± 0.289 mm./15 minutes.

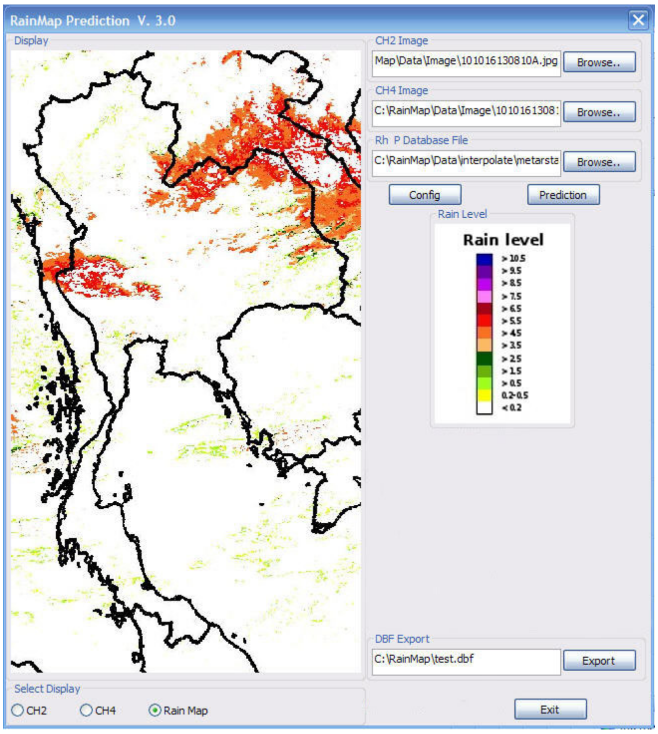

Figure 7. Rainfall map output by near-real time rainfall estimation program.

	A	B	C	D	E	F
1	ID	LATITUDE	LONGITUDE	X	Y	RAINRATE
2	1	20.92832	97.04168	0	0	0.00000
3	2	20.92832	97.05832	0	1	0.00000
4	3	20.92832	97.07495	0	2	0.00000
5	4	20.92832	97.09159	0	3	0.00000
6	5	20.92832	97.10823	0	4	0.00000
7	6	20.92832	97.12486	0	5	0.00000
8	7	20.92832	97.14150	0	6	0.00000
9	8	20.92832	97.15813	0	7	0.00000
10	9	20.92832	97.17477	0	8	0.00000
11	10	20.92832	97.19140	0	9	0.00000
12	11	20.92832	97.20804	0	10	0.00000

Figure 8. Rain rate data base output by near-real time rainfall estimation program.

CONCLUSION

1. The results of CH_2 and CH_4 gray scale values with raining data analysis, The gray scale values of APT is opportunity to raining can be categorized into 2 groups as follow,105-149 of CH_2 with 135-149 of CH_4 and 105-239 of CH_2 with 225-255 of CH_4.

2. The results of raining condition analysis, the RH has more than 80% meant having rain fall opportunity about 95% and that was less than 60% meant have 100% no rain fall.

3. The rainfall estimation program has rain/no rain position error about 10.21% and rain rate error about ± 0.289 mm./15 minutes.

RECOMMENDATION AND FURTHER IMPROVEMENT

With experience gained from this study, the recommendation for further study that expect the better result is related to improvement of program development as the followings.

1. The rainfall positions have less accuracy because the small number of METAR stations. The RH and P used in the program have low spatial resolution. The RH and P data from other weather stations should be added to cover the study area.

2. Near-real time rainfall estimation program can be applied to the normal seasonal rainfall. It cannot be applied to the rainfall during the monsoon storm because the rainfall data used to analyze should be the rain that fall during the normal.

3. Near-real time rainfall estimation program can be used during daylight hours only because there are not CH_2 of APT image in night time. The rainfall estimate program use the CH_3 and CH_4 of the APT image for night time should be developed.

4. A program that can forecast rainfall for about 1-2 hours in advance by add wind speed and wind direction data should be developed.

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