Analysis of Rainfall Rate by a Doppler Radar Image

Sujitra Arwatchananukul[*] and Panipa Phaiboonnimit

Department of Computer Science, Faculty of Science, Chiangmai University, Chiang Mai, Thailand, 50200.

*Corresponding Author. E-mail address: sujitra.ar@hotmail.com

Abstract

In Thailand, Royal rain radar is an effective tool to measure and monitor rain continuously. In addition, it is useful for planning, evaluation, and flood warning.

Therefore, the propose of this paper is to analyses rainfall rate systematically by a Doppler radar image based on digital image process. This system uses 646x644 pixel-GIF image as an input for finding all considered clouds. Then, it classifies dBz reflective signal levels by using ZR relationship, $Z = 300R^{1.4}$, to calculate the average rainfall rate. According to the rainfall testing data in 15 days with 200 Doppler radar images compared to data of 20 rain gauges at a random period. It is found that the error of calculated rainfall is 36.82 % on the total average deviation.

Introduction

In meteorology, rainfall is one of vital factors to study or improve efficiency of artificial rains. To do an analysis, we need data which represents quantity and distribution of rainfall based on any time and regions more than data of rainfall at specific area.

A huge basin of a river is a good location that represents rainfall based on quantity and distribution in an immense area. However, finding a good representative of actual rainfalls with correctness and reliability is so difficult. This may be naturally caused by a high variation based on time and considered area. For example, there is some raining in one side of the road but which not in another side. Therefore, the measurement of rainfalls by using some standard rain gauges is not good representatives of actual rainfalls in that area.

According to the problem, this made us interested in the Royal rain radar which measures rainfall. An advantage of using radar is to measure rainfalls in large area far from the check station (point) and to be able to spend only a few minute to within a few minutes to report the coverage of rainfall rate in every area. Additionally, radar shows desired data which consists of coordinates and density of rains, called a *Doppler Radar Image.*

In prior research, it was found that the distinctive point of a radar is the exhaustive result based on time and area that we can apply image processing theory to analyze rainfall rates which are similar to the results from rainfall meter or rain gauges. Therefore, this paper proposes an analysis of rainfall rate by Doppler radar images from the Royal rain radar. Moreover, this is another way to apply GIS technology for computing rainfall rates conveniently and easily.

Reference Theory

2.1 Weather Radar System

Radio Detection and Ranging (RADAR) is a tool used to search location of target or object using radio signal and gauge direction and distant of the target.

The principle of radar detection is to generate electro-magnetic wave. When it hits the target part of the electro-magnetic will bounce back. The weather radar detection with preset electro-magnetic wavelength would bounce the signal from the droplets in the cloud as shown in figure 2.1. The machine will then convert the signal to be the intensity. The larger the size and quantity the droplets, the more intense the signal. Moreover, radar detection sweeps around the post, therefore the result will identify the data of the cloud around the radar station area.
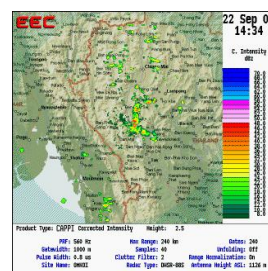

Figure 2.1 the result of measurement by weather radar

2.2 Calculating of Rainfall Rate by Radar Reflectivity Factor (Z)

From the principle that the amount of the bounced back energy will depend on the amount of cubic volume

of the weather, the result will be shown in form of reflectivity factor (Z) that is the electrical energy from Z.

In prior research under rainfall analysis development using the Royal rain radar project of Research Center in the Northern Thailand, the results of rainfall in Amphur Omkoy, Chiang Mai, and rainfall meters with automatic record system are used. Since most rains in Thailand are from clouds or even thunder rain clouds, the selected equation used to compute rainfall rate (RER) from radar data in this paper is relation between reflective radar and rainfall rate (ZR relationship), $Z = 300R^{1.4}$ where R is rainfall rate.

2.3 Colors to Black-White Image Conversion

This is a process converting a color image to represent only 2 levels, black and white. It converts image data to binary image. Additionally, it can convert images with several levels of intensities to only two levels of intensities by using one bit to represent 0 as white color, or 1 as black color. Then this binary image is the input of connected component labeling process.

2.4 Connected Component Labeling

This process is to define names for adjacent pixels in each area. Then, the number of distinct names indicates the number of areas in that image. Therefore, in binary image, the pixel on object area is assigned 1 when the other pixels as the background are assigned 0.

Step flow of System Operation

It is divided into 6 parts as following;

1) Part of Doppler Radar Image which has size of 646x644 Pixel and .gif file format. The Picture display in the program which is not viewed as Zoom since it is required the position of Coordinate X, Coordinate Y, Height and Width of the picture.

2) Part of Determination to process the picture or the part interested. If there is wanting to process only the part interested, please select Crop Tool to cut the part of picture needed to process or if there is wanting to process the whole picture, please select Hand Tool.

3) Part of Value Level Intensity (dBz) which needed to process the picture. The program has Intensity for 7 level which is the level of reflected signal typed dBz_8 dBz_{10} dBz_{12} dBz_{14} dBz_{16} dBz_{18} and dBz_{20} filtering the Intensity of picture of each level which needed to process.

4) Part of Using Math Lab Program in order to process picture. This part has structure of operation as following;

● Input a doppler radar image of .gif file format to be as data name and get Matrix value of the picture sized 646x644 Pixel and color table of picture.

● Cut the part which the color edge side the picture in order to find the intensity of color at the reflected signal typed dBz between 8- 68 dBz which will show the color and get color to calculate the color value in the picture map filtering only interested color only.

● Copy old color table of the picture to new color table in order to filter only color RGB which is between the color edge of the picture only since old color table keeps all color value RGB of the picture.

● Change type of picture to binary picture as the insertion of label of the point next to the type of 4 points.

● Cut only part of map of the picture which the user is interested to bring to process.

● Find the Connected Component Labeling by using 4 points method. This method can get amount of cloud.

● Calculate rainfall rate value, volume of rain water, area of cloud and average of rainfall rate of each cloud according to the theory.

Calculating formula of rainfall rate from Radar Reflectivity Factor (Z) as following;

I. *Calculate rainfall rate value by the formula*
$$Z = 300R^{1.4}$$
Hence, comes the rainfall rate (R)

$$R = (10^{(\log(Z/300))\ /1.4})/10 \quad millimeter/6minute$$

II. *Calculate the area of cloud equal amount of Pixel which each cloud is at different dBz* plus kilometer unit as 1 pixel is equal 1 square kilometer as following sample;

For example, 1st cloud has value at the level dBz_8 =10 pixel dBz_{14} =3 pixel and dBz_{16} = 5 pixel
So area of 1st cloud = 10+3+5 $(km)^2$
                                    = 18 square kilometers

III. *Calculate Rain Volume multiplying Rainfall* Rate with amount of cloud at the level different dBz to plus showing as following;

Rain Volume =
    (Area of cloud x Rainfall rate) dBz 8 $^+$
    (Area of cloud x Rainfall rate) dBz 12 $^+$...$^+$
    (Area of cloud x Rainfall rate) dBz 66 $^+$
    (Area of cloud x Rainfall rate) dBz 68

Suppose that the 1st cloud has value at the level dBz_8=10 pixel dBz_{14} =3 pixel and dBz_{16} = 5 pixel

At the level dBz_8 gets 10 pixels. Calculate Rain Volume = $10x1x10^6$ x 0.0003 $x10^{-3}$ = 3 volume.

At the level dBz_{14} gets 3 pixels. Calculate Rain Volume = $3x1x10^6$ x 0.0006 $x10^{-3}$ = 1.8 volume.

At the level dBz_{16} gets 5 pixels. Calculate Rain Volume= $5x1x10^6$ x 0.0008 $x10^{-3}$ = 4 volume.

So the 1st cloud has Rain Volume of = 3 + 1.8 + 4 = 8.8 volume.

IV. *Calculate average of rainfall rate value* by dividing volume of rain water of each cloud by

amount of pixel of the cloud showing as following;

> Average Rain Rate =
> Rain Volume of whole cloud / amount of pixel of whole cloud

As the sample in III) which is supposed that 1st cloud has value at the level dBz_8=10 pixel dBz_{14} = 3 pixel and dBz_{16} = 5 pixel showing that 1st cloud has rain volume at 8.8 volume and area of whole cloud is 18 pixel, so average of rainfall rate value is

Average Rain Rate = 8.8 / 18 $x10^6$

= 0.00048 milliter/6minute

5) Part of getting information after processing picture completely.

6) Last part is the part of report.

Experiment and Testing

The data of rain with Doppler Radar Image 200 images and the Rain Gauge in Northern of Thailand from Automatic Rain Gauge 20 stations are compared by using random period. The Weather Radar machine records every 6 minute, the record will be 10 pictures per one hour. The details are following:

The rainfall rate of actual measurement from rain gauge is compared to the rainfall rate from the program. The examples of the calculation are following:

The rainfall rate from rain gauge is 2 milliliters and from calculation is one milliliter.

Therefore, the deviation is equal to

$$\frac{(2-1) \times 100}{2} = 50 \%$$

Conclusion

The result of testing program

1) The result of data by program calculation, can explain to the level and movement a rainfall and the start time of rainfall to the end time of rainfall.

2) The program can categorize the rainfall for each time of measurement picture. It cans calculate the area of rainfall correctly.

3) The rainfall data of calculate by the high constant of the altitude is 2.5 kilometer and equation of Z-R relationship ($(Z=300R^{1.4})$ every 6 minute. The data is taken to compare with the rainfall data of one point directly. The total average of the result is 36.82 %. That mean the program show the result with the accuracy of 63.18 %, then the rain gauges is had the relationship of program quite little. Although the result of calculated is inaccurate the rainfall rate but it can be applied to study statistically about physical and behaviors of rainfall in the North of Thailand. The result data can be used in the research for the weather to make the Royal rain and predict the flood.

Table 4.1 Show the result of program

Point	Station	Coordinate		Date	Time	Rainfall Rate		Error	Error (%)
		Longitude	Latitude			Rain Gauges	Doppler Radar Image	Error	(%)
1	San Kham Pang	99.1196	18.7425	10/6/2005	16.00-14.00	2.2	2.0	0.2	9.09
2	Chiang Dao	98.9632	19.3681	10/6/2005	21.00-22.00	5.6	4.7	0.9	16.07
3	Pa Sang	98.9353	18.5181	16/6/2005	19.00-20.00	1.2	1.6	-0.4	33.33
4	Lam Phun	99.0054	18.5743	18/6/2005	15.00-16.00	0.6	0.3	0.3	50.00
5	Nong Tong	98.958	18.6137	29/6/2005	12.00-00.00	0.2	0.2	0	0.00
6	Mae Wang	98.7789	18.6131	3/7/2005	15.00-16.00	0.8	0.4	0.4	50.00
7	Mae Klang Waterfall	98.6693	18.4886	5/7/2005	13.00-14.00	4.2	6.8	-2.6	61.90
8	Ban Thi	99.1292	18.6502	9/7/2005	16.00-17.00	0.8	0.7	0.15	18.75
9	Phumipol Dam	99.0153	17.2457	13/7/2005	08.00-09.00	13.0	15.2	-2.2	16.92
10	Ban Hong	98.8121	18.3005	13/7/2005	15.00-16.00	2.8	1.5	1.3	46.43
11	Mae Ngat Dam	99.0129	19.1479	19/7/2005	16.00-17.00	2.0	1.9	0.14	7.00

Table 4.1 Show the result of program (continue)

Point	Station	Coordinate		Date	Time	Rainfall Rate		Error	Error (%)
		Longitude	Latitude			Rain Gauges	Doppler Radar Image		
12	Ban Khi Lek	98.9435	19.0138	25/7/2005	22.00–23.00	0.2	0.3	−0.1	50.00
13	Thung Hua Chang	99.0353	17.9899	26/7/2005	09.00–10.00	0.6	0.7	−0.1	16.67
14	Doi Sa Ked	99.1332	18.8677	26/7/2005	20.00–21.00	1.6	0.9	0.7	43.75
15	Li	98.9493	17.7987	11/8/2005	13.00–14.00	6.2	5.8	0.4	6.45
16	Suan Bua Resort	98.8465	18.7824	11/8/2005	13.00–14.00	0.2	0.5	−0.3	150.00
17	Hod	98.612	18.1738	13/8/2005	02.00–03.00	1.2	2.5	−1.3	108.33
18	Ta Pae	98.9981	18.7875	13/8/2005	02.00–03.00	8.6	6.8	1.8	20.93
19	Ban Tak	99.0732	17.0435	27/8/2005	15.00–16.00	0.2	0.2	0	0.00
20	Doi Chai	99.1279	18.4573	9/9/2005	02.00–03.00	2.6	3.4	−0.8	30.77
							Total Average:		36.82