Low Cost NOAA Satellite Receiving System for Rainfall Prediction

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Abstract. This article proposes, construct, and installs a low cost the Automatic Picture Transmission (APT) image receiving system from National Oceanic and Atmospheric Administration (NOAA) satellites for rainfall prediction. The APT receiving equipment includes crossed-dipole antenna, RF per-amplifier, radio receiver and PC computer with APT decoder software. The APT receiving system can receive APT images properly while NOAA satellites pass over Thailand. The rainfall prediction program uses Python language. This program estimates the position of rainfall/ no rainfall and amount of rainfall. The position of rainfall estimation model uses the gray scale value of APT images obtained from the Advance Very High Resolution Radiometer (AVHRR) channels 2 and 4 with relative humidity (RH) and air pressure (P) from Meteorological Aviation Report (METAR) data at 11 airport stations around of Thailand. The amount of rainfall model used the relationship between the gray scale value of channels 2 and 4 of APT image with rainfall value from the rain measurement stations. The rain rate equation can expressed as Rain rate = -7.046 + (0.046 * CH_2) + (0.012 * CH_4) - 0.539, the units are in millimeters per 15 minutes (mm. / 15 minutes). CH_2 and CH_4 are the gray scale values of the APT image from the AVHRR channels 2 and 4, and represent values of 0 to 255 respectively. The rainfall prediction program can be applied to the normal rainfall. It can not be applied to rainfall in a monsoon storm and can be used only in daytime.

Keywords: Rainfall Prediction, Automatic Picture Transmission, APT Receiving System, NOAA Satellite

1. Introduction

Rainfall is the most important climatic element especially in the tropics because it determines many agricultural and hydrological activities, which are dominant in the economies of the developing countries. Most of the rainfall data in the region is derived from rain gauge records. The present network for rainfall monitoring around the world by conventional means is deficient in many ways. Important near-real time or real time uses of rainfall data are found in weather forecasting, water management and flood control because they complement conventional data in space and time. Rain gauge is a direct measurement of rain but there is no coverage over oceans or remote regions. Rain gauge supports temporal resolution but its weakness is in the quality of spatial resolution. This is a problem and many studies have been undertaken in search of alternative methods of collecting data. Methods are now available in the form of a satellite system to help overcome the deficiency of rain gauge networks by means of remote sensing. The satellite system uses images from satellite and offers a wider area, real-time data which is of great importance in meteorology, hydrology, climatology and agriculture applications. Some data from satellites can be obtained free of charge. Normally, one drawback is that the ground receiving signal system is extremely complicated. However, there are some satellites that provide free information which can be used with uncomplicated and low cost receiving system. The APT from NOAA satellite is one of them. The APT system is an analogue image transmission system developed for use on weather satellites. For more than four decades, it has provided image data to relatively low-cost user stations at locations in most countries of the world. A user station anywhere in the world can receive local data at least twice a day from each satellite as it passes nearly overhead. The APT data has many applications such as, Land Surface Temperature (LST) and Cloud Top Temperature (CTT) analysis, cloud classification, and rainfall estimation.

Therefore, the author intends to develop a low cost rainfall prediction program using NOAA/APT receiving system. This receiving system is composed of crossed-dipole antenna, Very High Frequency (VHF) pre-amplifier, VHF receiver, APT decoder software and developed rainfall prediction program. The research

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requires gray scale values of the APT image from the AVHRR channels 2 and 4 to be incorporated with meteorological data such as rainfall, relative humidity, and pressure from ground stations.

1.1. APT system

The APT system is analogue transmission of data stream from the Advance Very High Resolution Radiometer instrument on NOAA satellites. It transmits the data continuously broadcasted in form of a radio wave on the 137 MHz frequency band. The NOAA satellites send APT images to anywhere in the world and the users can receive local images in real time. The APT image consists of two 4 km/pixel low resolution images derived from two channels. One channel is typically a thermal infrared channel 4 10.8)micrometers(. The second channel switches between near infrared channel 2 (0.86micrometers) and mid infrared channel 3 (3.75micrometers) depending on day or night time of the satellite orbit. The NOAA ground control stations can configure the satellite to transmit any two of the AVHRR channels [1]. At the present, the user can receive APT data from each satellite (NOAA15, NOAA18 and NOAA19) [2], twice a day.

The basic component of APT receiving system consists of omni-directional antenna, RF pre-amplifier, receiver, and computer with sound card and APT decoder software, as seen in Figure 1.

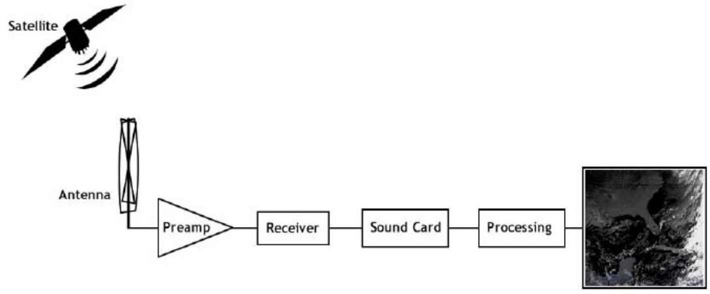

Fig. 1: APT signal receiving system block diagram [3].

1.2. Satellite imagery for rainfall prediction

There are many different methods of rainfall estimation, prediction and forecast. Recently, the most interesting methods to estimate rainfall using satellite-based sensors have been developed because the methods have high spatial and temporal resolution. The data can be derived from the satellites that are used primarily for meteorological purposes. Some have polar orbits such as the NOAA, the Feng-Yun 1 (FY-1), the Defence Meteorological Satellite Programs (DMSP), and others are geostationary satellites such as the Geostationary Operational Environmental Satellite (GOES), the Geostationary Meteorological Satellite (GMS), Feng-Yun 2 (FY-2), the Multi-functional Transport Satellite (MTSAT). Rainfall researchers, Cheng, K. S. and Wei, C. studied a real-time rainfall forecasting in Taiwan using thermal infrared band imagery from GMS weather satellite. They used a multi-spectral spatial convolution (MSSC) technique and a Kalman filtering algorithm for real-time parameter update [4]. Also, Suh, et al. estimated rainfall at southern Korea in June to August 2003 [5]. Their rainfall estimation technique used the infrared data from GOSE 8 and 9 to compute real time rainfall amounts based on a power- law regression algorithm. Tao, C. and Takagi, M. used a relationship between infrared and visible imagery from GMS images to forecast rainfall precipitation [6].

2. Methodology

Basically, the processes of the low cost NOAA satellites receiving system for rainfall prediction research consist of 3 parts as shown in Figure 2. First, hardware was assembled and installed which can receive the APT signal from NOAA satellites: NOAA 15, NOAA 18 and NOAA 19. Second, a program of rainfall prediction was developed using the Python language. The program was composed of climatic condition analysis which applied a gray scale value from APT images, RH and P from near-real time meteorological data from METAR report, and rain rate estimation analysis. Third, selected NOAA/APT images were used as input into the program and the results were validated by an accuracy assessment.

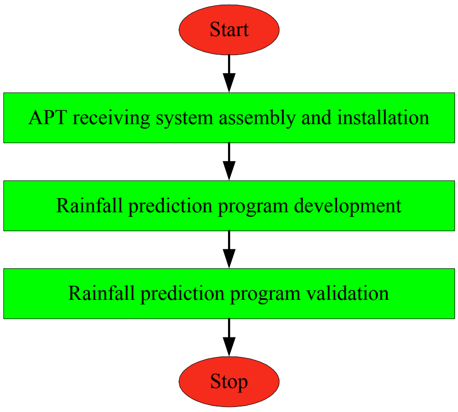

Fig. 2: Diagram of research process.

2.1. APT receiving system assembly and installation

The APT receiving system was assembled from hardware as follows:

- The crossed-dipole antenna, as shown in Figure 3, is an omni-direction and right circular polarized antenna. This exactly matches the antenna pattern from the satellite. The crossed-dipole antenna consists of two 1/2 wavelength horizontal dipoles that were oriented 90 degrees from each other. A phasing line was used to connect one dipole 90 degrees out of phase to the second one for circular polarization and crossed reflector. The antenna elements and reflectors were made from aluminium tube. The length of dipole elements is 50 cm. whereas the length of reflector elements is 105 cm. The span between crossed dipole to crossed reflector is about 50 cm.

Fig. 3: Crossed-dipole antenna.

- RF pre-amplifier was assembled from Hamtronics model LNK-137 kit [7]. This model can operate in 130 – 160 MHz frequency range, bandwidth 4 MHz, and gain 18 dB. as shown in Figure 4. The operating frequency of preamplifier was tuned to be 137.50 MHz to match with APT signals. Through a coaxial cable, the receiver can supply DC 12V power to the preamplifier and the amplified signals can then be fed to the receiver.

Fig. 4: RF pre-amplifier.

- The FM receiver was assembled from an Emgo model RX137141MHz kit [8] as shown in Figure 5. This model can operate in 137-141 MHz frequency range which covers the APT signal. The APT carrier frequency for each NOAA satellite can be controlled by WXtoImg software [9] via RS-232 cable. It performs FM signals demodulation to the AM 2,400 Hz sub-carrier (audio wave) and sends the signal to the sound card in the PC system.

Fig. 5: FM receiver.

APT receiving system installation

- APT receiving system (Figure 1) consists of the hardware i.e. crossed-dipole antenna, RF pre-amplifier, FM receiver, sound card and APT decoder software in a PC system. This receiving system was installed at 13° 51’ 14.03” N and 100° 36’ 28.28” E at approximate 6 kilometres from Don Maung airport in Bangkok.

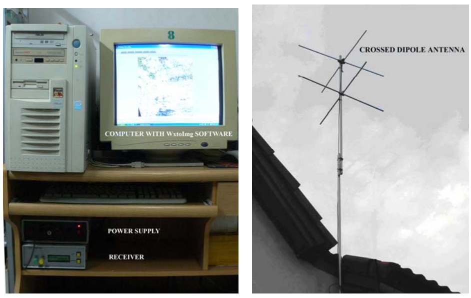

Fig. 6: APT receiving system installation.

2.2. Rainfall prediction program development

Chonmapat, T. developed the rainfall prediction program using the Python language [10]. This program can predict the position of rainfall / no rainfall and quantity of rainfall. The program process structure consists of: 1. input data from channel 2 and 4 of APT image into Thailand area, and from RH and P data from 11 airport stations in .dbf format. 2. Geo-referenced APT image in each pixels. 3. Interpolated RH and P point data convert point data to surface data over APT image area. 4. The climatic analysis for raining conditions is the process to the positions which have the opportunity to rain. 5. The rain rate calculation. 6. Output generation of a rainfall prediction map. The rain rate value is displayed by colour scale.

2.3. Rainfall prediction program validation

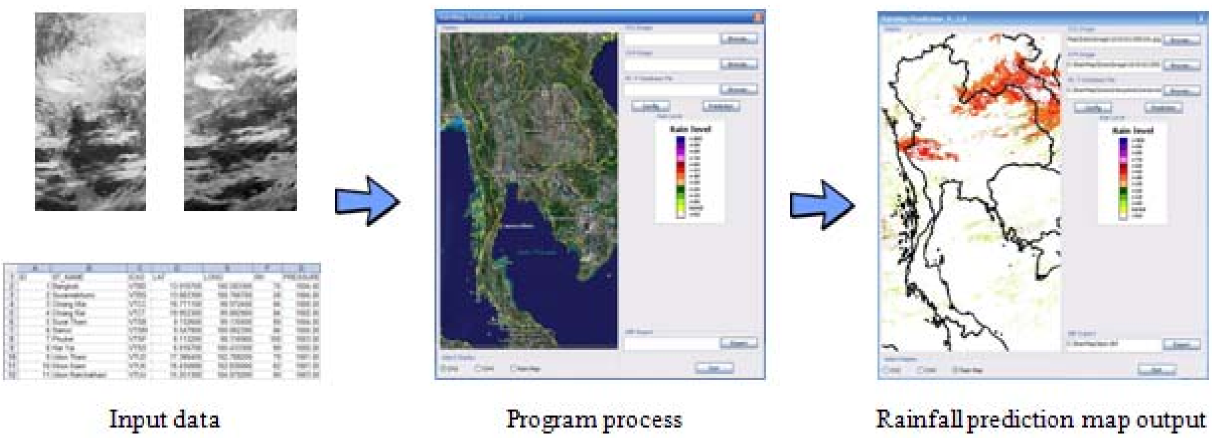

Fig. 7: Rainfall prediction program process.

Selected APT images in June-August 2010 were processed and employed to validate results from the rainfall prediction program. To validate the developed rainfall prediction program is to take the results from the program to compare with the rainfall values measured from 71 rainfall measurement stations in Bangkok. Due to the fact that the actual time interval of rainfall measurement is in every 15 minutes.

3. Results

The principle of the rainfall prediction program design is to combine raining condition analysis and the regression equation for rain rate estimation. This was developed by using Python language. The rain rate values on the map output are displayed by colour scales and rain rate point data which are in the unit of 15mm minutes, as shown in Figure 7. The output rain rate point data can be further generated to be GIS layer of grid point data with attributes of rain rate estimated from a regression equation.

The rainfall prediction program was tested with APT images and METAR reports during June to August 2010. To test the program, 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 test results found that the position of rainfall / No rainfall estimation error was approximately 10.21% and quantity of rainfall error were approximately ± 0.289 mm./15 minutes. In addition, the program could produce an output map within 10 minutes after received APT image.

4. Conclusions

The main objective of this research is to construct low cost and easy installation NOAA/APT receiving system and develop rainfall prediction model. The input data of the model are gray scale of APT image channel 2 and 4 with ground meteorological data include RH and P the rainfall model which can return the spatial rain condition and rain rate. However, bi-spectral technique cannot be applied to rainfall prediction during the night because no near infrared (channel 2) of APT image. The rainfall model was developed as the module using Python language. In this study, all raining values were used for analysis. Data with very low rainfall rate can cause low accurate result. Again, samples used for analysis could be reduced significantly because of the limited number of APT images recorded at the same time of rainfall recorded by Thai Meteorological Department.

5. References

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