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Estimation Analysis of Rainfall Based on Weather Radar Measurements

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Abstract **– Rainfall estimation based on radar measurements using neural network is a nonparametric method for representing the relationship between radar measurements and rainfall rate. The relationship is derived directly from a dataset consisting of radar measurements and rain gauge measurements. Data collected by a Weather Surveillance Bhopal 2008-2012 and a rain gauge network were used to evaluate the performance of the adaptive network for rainfall estimation to provide parameters for a closed-form rain-rate probability distribution model. It is shown that the adaptive network can estimate rainfall fairly accurately. In this paper we are taking the last five years (2008-2012) data from weather radar data at Bhopal in M.P. Region, India. With the help of this data we are trained the neural network. This project has been addressed two approaches. a) we are estimating the five years rainfall data month wise basis, b)The second problem we prepared analysis of five years rainfall data and make rainfall prediction model so on the basis of 2008 to 2012 basis we are made 2013 model to predict the rainfall and also its estimation.**

Keywords **– Rain gauge, ANN, Rain-rate probability, Radar rain data.**

I. Introduction

Radar can estimate precipitation over a large area (of order 240 kIn radius) with high spatial (of order 1-4 kIn) and temporal (of order 10 minute) resolution. Rain-gauges, the standard measurement of rainfall, make essentially sparse point measurements. A very dense network of rain gauges is required to match the radar detected precipitation fields due to the spatial and temporal variability of rainfall. This is costly and not practical. The ground rainfall estimation can be viewed as a complex function approximation problem. This technique includes two stages, namely, 1) the training and validation stage and 2) the application stage. In the training stage, the neural network learns the potential relationship between the rainfall rate and the radar measurements from a training dataset. When a radar measurement set is applied to the neural network, the network yields a rainfall-rate estimate as output. This output is compared with the rain gauge measurement, and their difference or the error is propagated back to adjust the parameters of the network. This learning process is continued until the network converges. Once the training process is complete, a relationship between the rainfall rate and the radar measurements is established and the network is ready for operation.

II. Artificial Neural Network

An artificial neural network (ANN), usually called neural network (NN), is a mathematical model or computational model that is inspired by the structure and/or functional aspects of biological neural networks. A neural network consists of an interconnected group of artificial neurons, and it processes information using a connectionist approach to computation. In most cases an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase. Modern neural networks are non-linearstatisticaldata modeling tools. They are usually used to model complex relationships between inputs and outputs or to find patterns in data.

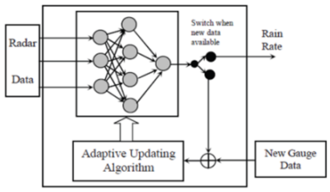

Fig.1. Adaptive Neural Network System for Ground Radar Rainfall Estimation

The neural network is trained using the reflectivity vertical profiles of the ground radar as input and the corresponding rain gauge measurements as a target. This neural network is trained adaptively and weights are updated in daily base. The reflectivity vertical profiles are taken starting at 1 km and going up to 4 km with 1km vertical resolution. The target of the neural network is the 5-minute average of gauge measurement. Rainfall estimation is done using the model of the previous day. The whole process of training the network is shown in Figure 1. Figure 2 shows detailed diagram for the process of rainfall estimation and system evaluation.

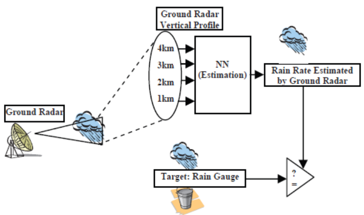

Fig.2. Adaptive Neural Network: system testing and evaluation

Weather radars send directional pulses of microwave radiation, on the order of a microsecond long, using a cavity magnetron or klystron tube connected by a waveguide to a parabolic antenna. The wavelengths of 1 to 10 cm (4 in) are approximately ten times the diameter of the droplets or ice particles of interest, because Rayleigh scattering occurs at these frequencies. The volume of air that a given pulse takes up at any point in time may be approximately calculated by the formula $V=hr^2\theta^2$, where v is the volume enclosed by the pulse, h is pulse width (in e.g. meters, calculated from the duration in seconds of the pulse times the speed of light), r is the distance from the radar that the pulse has already traveled (in e.g. meters), and $\theta$is the beam width (in radians). This formula assumes the beam is symmetrically circular, "r" is much greater than "h" so "r" taken at the beginning or at the end of the pulse is almost the same, and the shape of the volume is a cone frustum of depth "h" Between each pulse, the radar station serves as a receiver and listens for return signals from particles in the air. The duration of the "listen" cycle is on the order of a millisecond, which is a thousand times longer than the pulse duration. The length of this phase is determined by the need for the microwave radiation (which travels at the speed of light) to propagate from the detector, to the weather target, and back again, a distance which could be several hundred kilometers. The horizontal distance from station to target is calculated simply from the amount of time that lapses from the initiation of the pulse to the detection of the return signal. (The time is converted into distance by multiplying by the speed of light in air) :

$$\text{Distance} = c\frac{\Box t}{2n}$$

(c = speed of light = 299,792.458 km/s, n = refractive index of air ~= 1.0003[10]).

If pulses are emitted too frequently, the returns from one pulse will be confused with the returns from previous pulses, resulting in incorrect distance calculations.

Depending on the elevation angle of the antenna and the other considerations, one can calculate the height above ground of the target with this formula.

$$H = (\sqrt{r^2 + (Kea)^2 + 2rKeAsin\,\theta e} - Kea + ha$$

Where,

r = distance radar-target, k_e = 4/3, a_e = Earth radius, θ_e : elevation angle above the radar horizon, h_a : height of the feed horn above ground.

Each weather radar network use a series of typical angles that will be set according to the needs. After each scanning rotation, the antenna elevation is changed for the next sounding. This scenario will be repeated on many angles to scan all the volume of air around the radar within the maximum range.

Calibrating intensity of return

Because the targets are not unique in each volume, the radar equation has to be developed beyond the basic one

$$Pr = \{Pt * \frac{G^2\lambda^2\,\sigma o}{(4\pi)^3\,R^4}\}\,\alpha\,\frac{\sigma o}{R^4}$$

where Pr is received power, Pt Is transmitted power, Gt is the gain of the transmitting antenna, λ is radar wavelength, σ is the radar cross section of the target and R is the distance from transmitter to target.

III. Rain Gauge

A rain gauge (also known as a udometer or a pluviometer or an ombrometer or a cup) is a type of instrument used by meteorologists and hydrologists to gather and measure the amount of liquid precipitation over a set period of time. Most rain gauges generally measure the precipitation in millimeters. The level of rainfall is sometimes reported as inches or centimeters. Rain gauge amounts are read either manually or by automatic weather station (AWS). The frequency of readings will depend on the requirements of the collection agency. A rain gauge is a piece of apparatus left outdoors, which collects water during rain. The user reads the amount of water off a scale. You can use a vertical-sided container, and make your own measurements of the water depth. For meteorological purposes, a commercially manufactured instrument is used. For precision, especially when falls are light, the gauge has a funnel, so that the water from a larger area is gathered into a narrower area. This means that the scale has to be enlarged, giving better readings.

Types of rainguage:

Types of rain gauges include graduated cylinders, weighing gauges, tipping bucket gauges, and simple buried pit collectors. Each type has its advantages and disadvantages for collecting rain data.

1) Standard rain gauge

The standard rain gauge, consists of a funnel emptying into a graduated cylinder, 2 cm in diameter, that fits inside a larger container which is 20 cm in diameter and 50 cm tall. If the rainwater overflows the graduated inner cylinder, the larger outer container will catch it. When measurements are taken, the height of the water in the small graduated cylinder is measured, and the excess overflow in the large container is carefully poured into another graduated cylinder and measured to give the total rainfall.

2) Weighing precipitation gauge

A weighing-type precipitation gauge consists of a storage bin, which is weighed to record the mass. Certain models measure the mass using a pen on a rotating drum, or by using a vibrating wire attached to a data logger. The advantages of this type of gauge over tipping buckets are that it does not underestimate intense rain, and it can measure other forms of precipitation, including rain, hail and snow.

3) Tipping bucket rain gauge

The tipping bucket rain gauge consists of a funnel that collects and channels the precipitation into a small seesaw-like container. After a pre-set amount of precipitation falls, the lever tips, dumping the collected water and sending an electrical signal. An old-style recording device may consist of a pen mounted on an arm attached to a geared wheel that moves once with each signal sent from the collector. In this design, the wheel turns the pen arm moves either up or down leaving a trace on the graph and at the same time making a loud click. Each jump of the arm is sometimes referred to as a 'click' in reference to the noise. The chart is measured in 10 minute periods (vertical lines) and 0.4 mm (0.015 in) (horizontal lines) and rotates once every 24 hours and is powered by a clockwork motor that must be manually wound.

4) Optical rain gauge

These have a row of collection funnels. In an enclosed space below each is a laser diode and a photo transistor detector. When enough water is collected to make a single drop, it drips from the bottom, falling into the laser beam path. The sensor is set at right angles to the laser so that

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enough light is scattered to be detected as a sudden flash of light. The flashes from these photo detectors are then read and transmitted or recorded.

5) Acoustic rain gauge

The acoustic disdrometer developed by Stijn de Jong is an acoustic rain gauge. The big advantage of this design is that it is a lot less costly. Rain gauges have their limitations. Attempting to collect rain data in a hurricane can be early impossible and unreliable (even if the equipment survives) due to wind extremes. Also, rain gauges only indicate rainfall in a localized area. For virtually any gauge, drops will stick to the sides or funnel of the collecting device, such that amounts are very slightly underestimated, and those of .01 inches or .25 mm may be recorded as a trace.Another problem encountered is when the temperature is close to or below freezing. Rain may fall on the funnel and ice or snow may collect in the gauge and not permit any subsequent rain to pass through.
Rain gauges should be placed in an open area where there are no obstacles, such as building or trees, to block the rain. This is also to prevent the water collected on the roofs of buildings or the leaves of trees from dripping into the rain gauge after a rain, resulting in inaccurate readings

IV. Working Operation

A representative training data set consisting of the radar data and corresponding ground raingauge data are needed to develop a multilayer perception for the rainfall estimation problem. Radar data and other related information are applied to the network as the input and the corresponding rain gauge data are used as the target or desired output. The training procedure for a multilayer perception includes two steps, namely forward propagation and backward propagation. The connectional weights are updated during the backward error propagation according to the learning algorithm. This process is repeated until the error between the network output and desired output (rain gauge measurement) meets the prescribed requirement. When the training process is complete, the network is ready for application. Rainfall estimates can be obtained if radar data are applied to the network at this stage.The estimated analysis of rain fall is shown in fig 3.

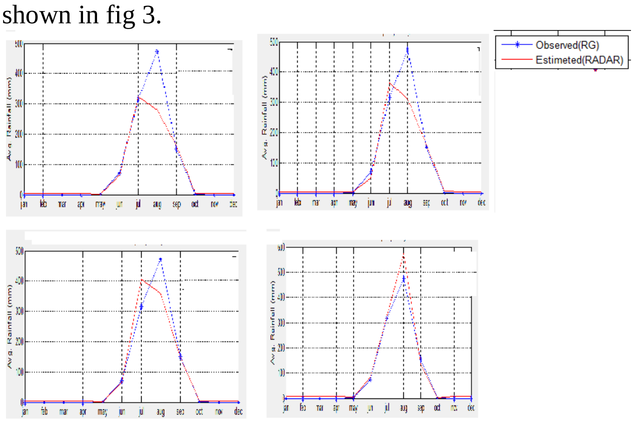

Fig.3. Estimated analysis for next four iteration

V. Conclusion

It provides the only model available for predicting monthly or seasonal probability distributions. It provides a solution to the worst month distribution estimation problem because distributions may be predicted for each of the months in a year and the worst one is then readily apparent. The model provides monthly and annual distribution predictions that match the observed distributions within the expected uncertainty produced by the intrinsic interannual variations in rain occurrence.The neural network is trained using the radar measurements as the input and the ground raingage measurements as the target output. The neural network based estimates are evaluated using data collected from ground radar experiment based on this data in Bhopal region M.P, India. The Rainfall estimation based on neural network to estimate rainfall is described here. This technique can be used for rainfall estimation. Data from years 2008, 2009, 2010, 2011, 2012 over Bhopal were used to evaluate the performance of this technique against rain gauge measurements. Also evaluate Rainfall Prediction Analysis Estimation for year 2013.Final Result is comparison Analysis of Actual rainfall Estimation and predicted rainfall. Also calculate the comparison analysis actual rainfall rate and predicted rainfall rate.

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