Rainfall Prediction Model based on Radar Image Analysis Processing

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Abstract: The radar image represents the intensity of the rainfall measured at the observatory by the image pixel color value. It is the goal of this paper to find that the radar image values at a given point calculate the rainfall at a given time. Correlation analysis between radar images and rainfall data provided by rainfall gauges installed at very rare intervals is performed first. Based on this correlation analysis, we find out how to calculate the rainfall in the area where AWS is not installed by radar image. The biggest challenge of this paper is to find a predictive model of rainfall that takes into accounts the movement patterns of radar images affected by wind direction, wind speed, temperature and humidity.

1 INTRODUCTION

Rainfall forecasts in the weather forecasts are not always accurate, so there is great dissatisfaction with the citizens. Existing rainfall is predicted using radar reflectivity data and terrestrial meteorological data collected by weather radar observation network. However, there is a problem that the accuracy of rainfall forecasts judged by rainfall radar images and forecasters' experience based on surface AWS data is low as can be seen in Table I.

Table 1: Sample rainfalls of Radar and AWS data.

Date	Radar Rain	Surface Rain
2017-09-11 6:00	3.85mm	1mm
2017-09-11 6:10	6.8mm	3mm
2017-09-11 6:20	6.53mm	4.5mm
2017-09-11 6:30	20.3mm	4.5mm

This paper aims to develop rainfall forecasting model through correlation analysis between weather radar value and ground rainfall observation value. Simple linear regression analysis shows that it is difficult to analyze the correlation between radar reflectivity data and surface rainfall.

To conduct the analysis using real data, we used the weather radar observations in Busan city (KMA, 2017). Actual rainfall radar image value is csv file, image value is color pixel and classified into 32 kinds according to rainfall type. The color of the radar image is mm of rainfall per hour and is updated every 10 minutes (KMA, 2017).

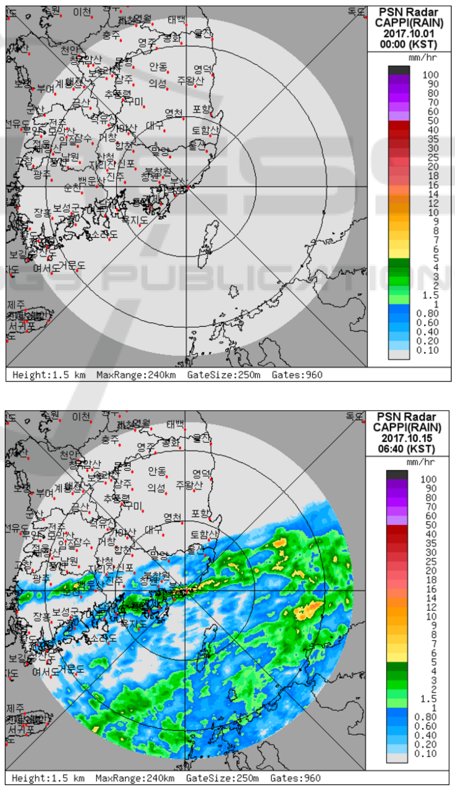

Figure 1: Radar Image for representing rainfall (KMA, 2017).

This paper deals with the problem of using rainfall radar image pixel color values to calculate rainfall at a given location and to develop a model to forecast

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future rainfall along the direction of rainfall. To analyze the relationship between rainfall radar images and rainfall at specific points, we develop rainfall calculation model by correlation analysis with AWS (automatic weather observation equipment) (KMA, 2017) and future wind speed-based prediction model considering various weather variables such as wind direction, wind speed, temperature and humidity.

Section 2 shows the results of correlation analysis between the rainfall radar image and the observed rainfall on the ground. We also define the problem of finding the best corresponding aerial position where the rainfall difference between the location of the ground observation point and the aerial position of the rainfall radar image is minimized. In Section 3, we show the difference between the rainfall calculated by the rainfall radar image and the rainfall measured by AWS (Automatic Weather System) on the ground. Based on these experimental results, it is shown that rainfall forecasting model based on radar image should be made as non-deterministic function. Section 4 explains the related research cases and concludes with a remaining breakthrough research topic in Section 5.

2 CORRELATION COEFFICIENT ANALYSIS

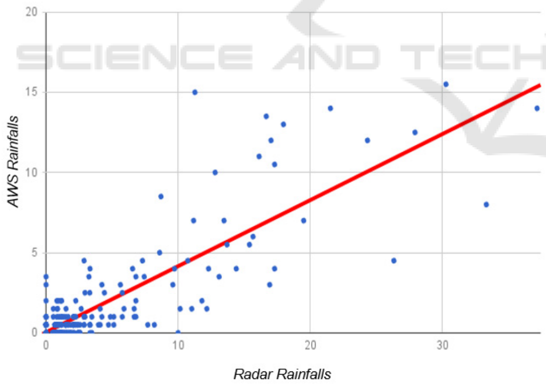

Figure 2: Correlation Analysis (Correlation Coefficient = 0.8501).

The correlation index between rainfall radar images and AWS measured rainfall is not constant. The rainfall data of the rainy season of July, August, September and October of 2017 were analyzed and the correlation index with the radar image was analyzed and it was 0.8501 as shown in Figure. 2. The more rainfall, the lower the correlation. In order to generate better model, we need to consider attributes that could influence the amount of rain, which are, wind speed, wind direction., temperature, and humidity.

2.1 Correlation with Wind Speed

We also analyzed the results of the analysis of wind speed as a weighting factor in the correlation analysis between rainfall radar image and AWS rainfall data. As shown in Figure. 3, the correlation index increases as the wind speed is included as a weight. The radar rainfall considering the wind speed can be calculated by following the Eq. (1).

$$Radar\_Rain_{wind} = Radar_{Rain} + d(\frac{windspeed}{k}) \quad (1)$$

k is a constant to determine how much the wind-speed should affect the calculation and we used k=12 in this current research. d is determined whether the rain is decreasing or increasing in the current time frame. d = -1 in the case of rainfall is decreasing where d = 1 in the case of rainfall is increasing. The correlation coefficient between rainfall and rainfall radar images affected by wind speed slightly increased to 0.8574.

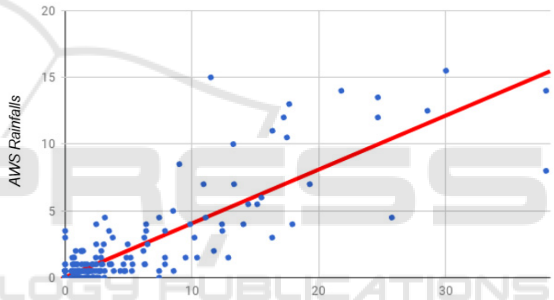

Figure 3: Correlation analysis considering wind speed (Correlation Coefficient = 0.8574).

2.2 Correlation with Wind Direction

The correlation index between the rainfall radar image considering the wind direction and rainfall was found to be rather low. Figure 4 shows that correlation coefficient is 0.5321 as a result of correlation index analysis considering east-southeast (ESE) wind direction.

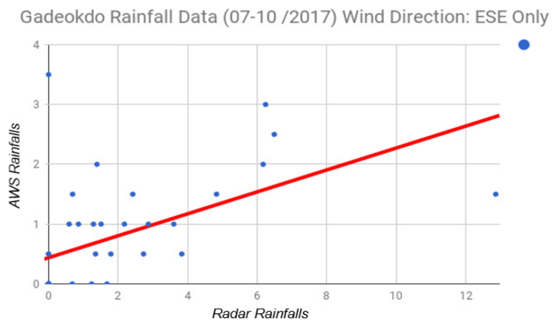

Figure 4: Correlation analysis using ESE wind direction (Correlation Coefficient = 0.5321).

2.3 Correlation with Temperature

We also conducted the research using temperature as a weighting factor in the correlation analysis between rainfall radar image and AWS rainfall data. As shown in Figure. 5, the correlation index increases as the temperature is included into the calculation. The radar rainfall considering the temperature can be calculated by following the Eq. (2).

$$Radar\_Rain_{temperature} = Radar_{Rain} - \frac{temperature}{k} \quad (2)$$

k is a constant to determine how much the temperature should affect the calculation. In this experiment we used k = 100. The correlation coefficient between AWS rainfall and radar image rainfall affected by temperature has been increased to 0.8754.

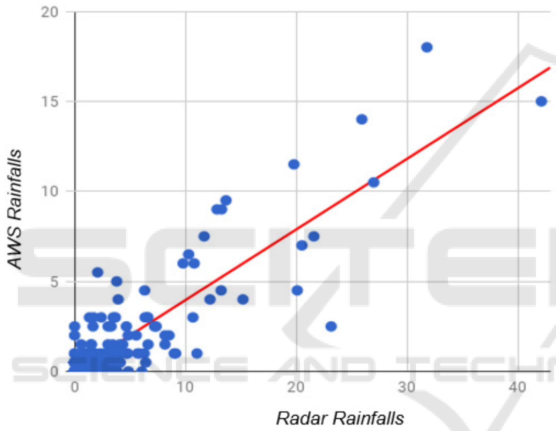

Figure 5: Correlation analysis considering temperature (Correlation Coefficient = 0.8754).

2.4 Correlation with Humidity

In addition to windspeed, wind direction and temperature, we also analyzed the correlation index between the rainfall radar and AWS rainfall using ASOS humidity data as weight. As shown in Figure. 6, the correlation index increases as the humidity is included into the calculation. The radar rainfall considering the humidity can be calculated by following the Eq. (3).

$$Radar\_Rain_{humidity} = Radar_{Rain} - \frac{humidity}{k} \quad (3)$$

k is a constant to determine how much the temperature should affect the calculation. In this experiment we used k = 100. The correlation coefficient between AWS rainfall and radar image rainfall affected by temperature has been increased to 0.8799.

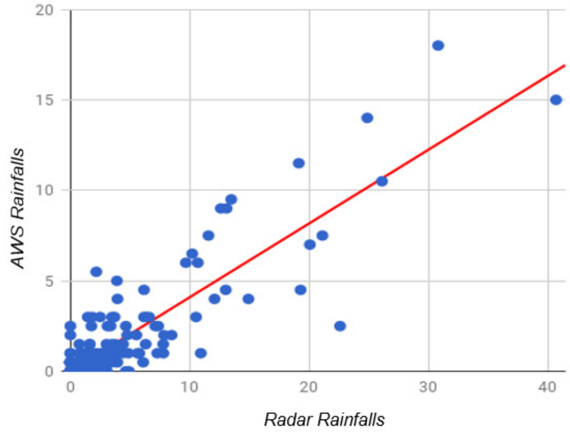

Figure 6: Correlation analysis considering temperature (Correlation Coefficient = 0.8799).

2.5 MLR Predictive Model

Finally, we used Multiple Linear Regression analyze to generate a more efficient prediction model, considering all major factors such as windspeed, temperature and humidity. This model achieved Correlation Coefficient result of 0.88. The equation of this model is detailed in Eq. (4) and Table II.

$$Y = -2.683 + 0.372X_1 - 0.002X_2 + 0.03X_3 + 0.025X_4 \quad (4)$$

Table 2: Description of MLR Model variables.

Variable	Description
Y	Predicted Surface Rain (mm/10min)
X_1	Radar Rain (mm/10min)
X_2	Windspeed (m/s)
X_3	Temperature (°C)
X_4	Humidity (%)

A method for finding the correspondence between the location of the rainfall radar image and the location of the rainfall observation point has been required. Correlation analysis confirmed that the rainfall is not the same even if the latitude and longitude coordinates of the radar image are the same for the ground rainfall observation point. Through these experiments, we propose a very breakthrough method to devise a method to locate the radar image nearest to the rainfall of the latitude and longitude coordinates.

Let P (x, y) be the position of the longitude and latitude of the observation point of the rainfall on the surface. Let the observed rainfall measured at the location P (x, y) where the rainfall system is installed is

RF (x, y). Let AP (a, b) be the aerial position of the radar image. Let the rainfall radar value observed at AP (a, b) be PR (a, b). It is necessary to obtain the latitude and longitude coordinates (a, b) of the radar image in which the difference between RF (x, y) and PR (a, b) becomes minimum for a given P (x, y). This analysis is based on the given longitudinal coordinates (x, y). The aerial position (a, b) of the radar image at which the value of min (RF (x, y) - PR (a, b)) would be minimum is obtained and then a new learning model is newly created for different weather conditions of wind direction, wind speed and temperature and humidity.

It is necessary to find out the same zone of the similar rainfall forecasts. In other words, it must be resolved to find and determine the boundary point where the minimum of the difference between RF (x, y) and PR (a, b) is maintained spatially and temporally. It is a break-through research theme to further discover that these boundary points are formed differently depending on the weather changes and the topographic form.

3 EXPERIMENTS

3.1 Experimental Environment

As we have mentioned in the previous section, in this experiment, we used the input data used the weather data in Busan region such as rainfall, windspeed, humidity, wind direction and temperature daily during July, August, September and October of 2017. To compare and generate the result of the MLR model, we pick all of the rainy days from each of those month. All these data were calculated using method shown in Section 2.

3.2 Experimental Results

As a result of both regression analysis and correlation analysis, correlation index between rainfall radar image and AWS image is 0.8 or more. However, it can be seen that the correlation index changes as the rainfall layer image value moves away from the observation point. When the wind speed, humidity, and temperature are included as a weight, the correlation index increases but the wind direction does not affect the correlation coefficient. The most important problem is to make an optimal algorithm of best matching a given ground AWS location with the corresponding aerial rainfall radar image.

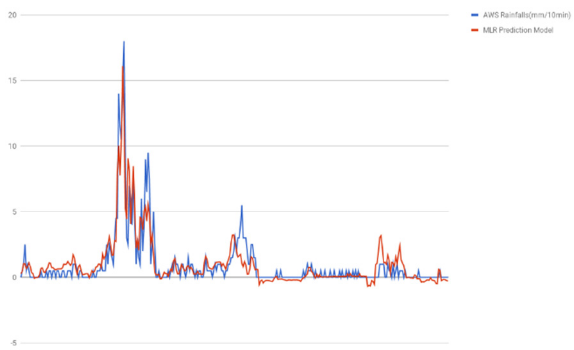

Figure 7: Multiple Linear Regression Model Result.

Figure. 7, compare the rainfall estimates using the correlation-based MLR model with the actual rainfall using the rainfall radar image value as the x value of the function. Rainfall radar images are physically and logically different from aerial rainfall locations as aerial observations. It is important to develop a rainfall prediction model that can accurately calculate the rainfall at a certain point because the rainfall radar image is synthesized from radar images produced from several radar observation devices. The rainfall prediction model should be a non-deterministic function that finds the aerial location (a, b) of the radar image with minimum difference between RF (x, y) and PR (a, b). Rainfall forecasting model based on rainfall radar image should be solved by development of data analysis model considering surrounding terrain in addition to wind velocity, wind direction, and temperature and humidity. By having this experimental result, we will be able to use it and focus on increase the accuracy of our predictive model through further research on analyzing the solution to fix the radar and AWS location problem.

4 RELATED WORKS

In previous works, some researchers have tried to use other method to estimate rainfalls. One of the method is using data mining and deep learning method to predict the rainfall. The researcher of this method had tried to combine radar data and AWS data with wind speed and wind direction during the CNN training process. However, a beneficial model was not found, and the research end up using only AWS data. The model was able to forecast rain in the next hour with over 90% accuracy but does not provide the amount of rainfalls data (Suryong, 2017). Another method is through using road CCTV camera which achieved over 87% of accuracy. However, the method requires

CCTV camera in the observation location and the radar weather data was not utilized to improve the accuracy rate in the estimation process (Lee, 2016).

5 CONCLUSIONS

The purpose of this paper is to solve the method of forecasting the amount of rainfall on the ground using radar images. However, it is difficult to find a effective rainfall forecast model only by analyzing radar images and existing rainfall data. Finding a big data analysis model as a method of forecasting the accurate rainfall is a breaking-through theme because the location of airborne radar image values does not coincide with the rainfall point on the ground and rainfall drop points depend on the wind direction and wind speed.

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