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St. Vincent Pallotti College of Engineering & Technology, Nagpur,

Radar data analysis using linear regression

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Abstract- **The unpredictable fluctuations in weather and atmospheric conditions have made weather forecasting an important subject of study. Scientists have created innovative techniques for training models to acquire precision over nonlinear statistical datasets over the past few decades to avert further environmental harm and global calamities. A new dimension to the field of weather forecasting has been added by Artificial intelligence and machine learning that requires only a few confusing mathematical equations. The motive of this examination is to analyze radar data. The implications of this study will feed into the field of climate prediction and weather forecast models. This research also shows a proposed model that demonstrates the correlation between different radar elements.**

Keywords- Radar Analysis, Linear Regression, Weather Elements, Correction

I. Introduction

Radar technology has been used for military purposes since World War II, but it wasn't until the 1950s that it became a powerful tool for weather forecasting. Since then, radar technology has advanced significantly and is now a key component of modern weather forecasting systems. Radar analysis uses the principles of reflection and refraction of electromagnetic waves to detect the position, movement and strength of the atmosphere such as precipitation and clouds.

Weather forecasts are an integral part of modern society, providing important information for safety, transportation and agricultural planning. Technological advances over the years have allowed meteorologists to improve their ability to accurately predict the weather. One of the most important technological advances in weather forecasting is the use of radar analysis. Radar analysis is essential in a variety of industries and applications, including military, aerospace, meteorology, and astronomy.

Following mentioned are of the main reasons why radar analysis is important are:

a. Object detection: Radar analytics can detect the presence, location and movement of objects in the air or on the ground. This information is important for air traffic control, military surveillance, and weather forecasting.

b. Weather Forecasting: Radar analysis is an important tool for meteorologists to track storms and forecast severe weather. Doppler radar can detect wind speed and direction within storm systems, enabling meteorologists to issue timely and accurate weather warnings.

c. Navigation: Radar analysis is used in navigation systems to determine the position and movement of ships and aircraft. This information helps pilots and sailors avoid collisions and stay on course.

Overall, a radar analysis application can help users extract valuable insights from radar data, improve situational awareness, and make more informed decisions in a variety of applications.

II. Literature Review

A. Radar Data Elements:

A radar file consists of Reflectivity, Velocity, Spectrum Width and Power.

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- **Reflectivity:** Images of reflectivity do exactly what they sound like they do: they depict the weather by using the energy reflected back to the radar. Reflectivity pictures make up the vast bulk of radar images you'll see on television. The colours show the intensity of the radar's returned energy, represented in decibel (dBZ) levels. The image's right side has the colour scale. The intensity of the downpour rises with the dBZ levels.Following gives criteria for reflectivity range:
    - Range 30 below: Normal
- Range 30-40: Moderate
- Range 40-50: Heavy Rain
- Range 50-60: Severe
- **Spectrum Width:** The fluctuation of the mean radial velocity estimations (movement) is caused by wind shear, turbulence, and/or the quality of the velocity samples. The decision-making process for severe thunderstorms and tornado warnings can be aided by spectrum width. It is used, among other things, to compute the turbulence at the low-level boundaries, and thunderstorms.
- **Wind Velocity:** Radar can only detect motion that is aimed directly towards or away from it. Because the target's motion goes in the same direction as the radar beam, this motion component is known as the "radial velocity of wind." The radial velocity is displayed in a style that is simple to see in the graphic below. The scatters' velocities are depictedby their colors. Positive velocity indicates cloud movement away from the radar, whereas negative velocity denotes cloud movement towards the radar.
- **Power:** A radar system's capacity to identify and follow targets is determined by its radar power. The quantity of energy transferred towards the target by the radar antenna determines how powerful a radar system is. The target returns the sent power, which the radar antenna picks up.The range, resolution, and accuracy of a radar system are all impacted by the power of the system. In addition to being able to determine the position, velocity, and size of the target with more precision and resolution, a higher power system can detect objects at greater distances.

B. Linear Regression

A branch of supervised machine learning is regression analysis. It seeks to represent the link between a set of features and a continuous target variable.A linear regression model explains the correlation between one or more independent variables (X) and a dependent variable (y). The term "response variable" also applies to the dependent variable. Explanatory or predictive variables and independent variables are both used interchangeably.

C. Scikit-learn

The most effective and reliable machine learning library for Python is called Scikit-learn (Sklearn). It provides a variety of rapid tools for statistical modelling and machine learning, including as dimensionality reduction, clustering, and classification, through a Python interface. NumPy, SciPy, and Matplotlib are the foundations for this primarily Python-written package.

III. METHODOLOGY

Here the system's architecture is depicted in the diagram. The reflectivity, power, spectrum width, and velocity values that are produced from each raw file are then utilized to further estimate correlation between these radar elements in a web application that retrieves radar data elements based on the current weather circumstances. The goal of creating a web application was to make the process of creating datasets from raw files in a batch much simpler. The user can download the crucial piece of information by simply entering the link to the folder containing raw files, as well as view the radar data elements in graphical format under "Weather Elements" section below. An excel spreadsheet containing the downloaded radar data is utilized as an input for a linear regression model.

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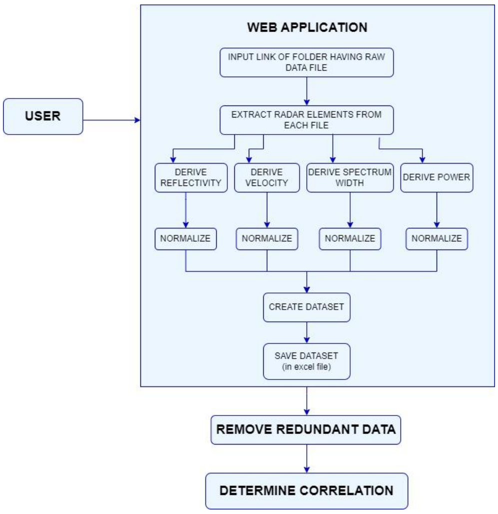


Figure 3.1 System Architecture

It was discovered that the numbers acquired from a single raw file were extremely large, and that this size varied from file to file. This was due to the fact that these values rely on the cloud cover that was present at the time the radar data was gathered. Example- Radar element values for a raw radar file was found in matrix size 3600x497. As a result, the data obtained for each radar element needed to be normalized. In doing so, NULL values were eliminated, unnecessary values were filtered out, and the most repeating value from each data file was taken into account. 547 raw files in a folder were considered for this study.

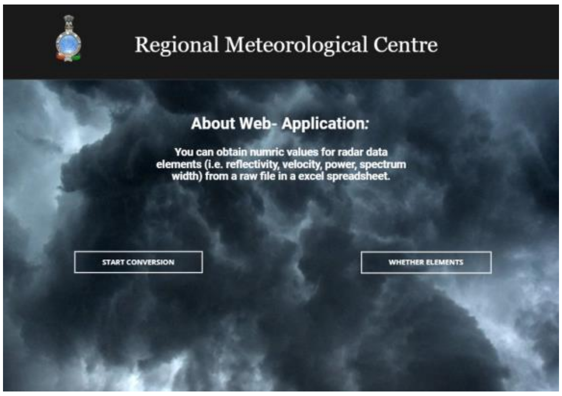


Figure 3.2 Home Page

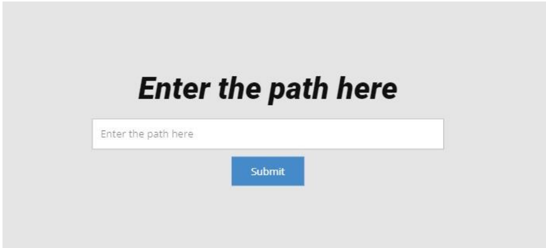
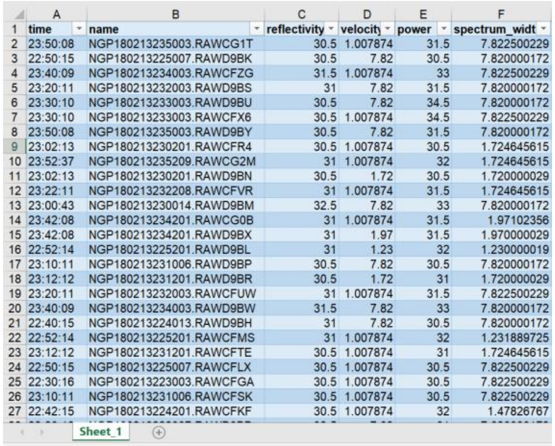


Figure 3.3 Folder link upload page



	A	B	C	D	E	F
1	time	name	reflectivity	velocity	power	spectrum_widt
2	23:50:08	NGP180213235003.RAWCG1T	30.5	1.007874	31.5	7.822500229
3	22:50:15	NGP180213225007.RAWD9BK	30.5	7.82	30.5	7.820000172
4	23:40:09	NGP180213234003.RAWCFZG	31.5	1.007874	33	7.822500229
5	23:20:11	NGP180213232003.RAWD9BS	31	7.82	31.5	7.820000172
6	23:30:10	NGP180213233003.RAWD9BU	30.5	7.82	34.5	7.820000172
7	23:30:10	NGP180213233003.RAWCFX6	30.5	1.007874	34.5	7.822500229
8	23:50:08	NGP180213235003.RAWD9BY	30.5	7.82	31.5	7.820000172
9	23:02:13	NGP180213230201.RAWCFR4	30.5	1.007874	30.5	1.724645615
10	23:52:37	NGP180213235209.RAWCG2M	31	1.007874	32	1.724645615
11	23:02:13	NGP180213230201.RAWD9BN	30.5	1.72	30.5	1.720000029
12	23:22:11	NGP180213232208.RAWCFVR	31	1.007874	31.5	1.724645615
13	23:00:43	NGP180213230014.RAWD9BM	32.5	7.82	33	7.820000172
14	23:42:08	NGP180213234201.RAWCG0B	31	1.007874	31.5	1.97102356
15	23:42:08	NGP180213234201.RAWD9BX	31	1.97	31.5	1.970000029
16	22:52:14	NGP180213225201.RAWD9BL	31	1.23	32	1.230000019
17	23:10:11	NGP180213231006.RAWD9BP	30.5	7.82	30.5	7.820000172
18	23:12:12	NGP180213231201.RAWD9BR	30.5	1.72	31	1.720000029
19	23:20:11	NGP180213232003.RAWCFUW	31	1.007874	31.5	7.822500229
20	23:40:09	NGP180213234003.RAWD9BW	31.5	7.82	33	7.820000172
21	22:40:15	NGP180213224013.RAWD9BH	31	7.82	30.5	7.820000172
22	22:52:14	NGP180213225201.RAWCFMS	31	1.007874	32	1.231889725
23	23:12:12	NGP180213231201.RAWCFTE	30.5	1.007874	31	1.724645615
24	22:50:15	NGP180213225007.RAWCFLX	30.5	1.007874	30.5	7.822500229
25	22:30:16	NGP180213223003.RAWCFGA	30.5	1.007874	30.5	7.822500229
26	23:10:11	NGP180213231006.RAWCFSK	30.5	1.007874	30.5	7.822500229
27	22:42:15	NGP180213224201.RAWCFKF	30.5	1.007874	32	1.47826767

Sheet_1

Figure 3.4 Downloaded excel file

A. Data Set Use in Testing

We have used the raw files of a particular day captured by radar at different intervals provided by Regional Meteorological Centre, IMD, Nagpur. The raw files are a special type of file format which contains data in multidimensional array format which we used to get a particular field using PY-ART library and further was converted single excel sheet to feed into the model.

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IV. EXPERIMENTAL RESULTS AND ANALYSIS

The amount of energy that a surface, like rain or a solid object, reflects back to the radar antenna is known as its reflectivity. More energy is released, and the radar is more sensitive to an object's reflectivity with a stronger radar signal.

The frequency of the radar signal, the kind of radar system being used, and the characteristics of the item being detected are only a few of the variables that affect the relationship between radar power and reflectivity. The position, intensity, and velocity of rain or other items can be detected and measured using a stronger reflected signal that is often produced by higher radar power.

Figure 4.1 Reflectivity vs Power (Training set)

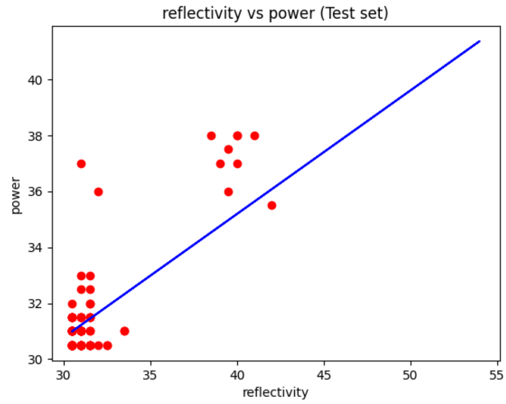

Figure 4.2 Reflectivity vs Power (Test set)

A wider spectrum width often denotes a greater variety of Doppler velocities in the radar return signal. Multiple targets, the presence of turbulence or air eddies, the movement of precipitation or other atmospheric phenomena are only a few causes that can result in this. The relationship between radar velocity and spectrum breadth, however, is not always clear-cut. For instance, a high-velocity target may occasionally have a narrow spectrum width if it is the only one in the radar beam, but a low-velocity target engulfed in turbulence may occasionally have a wider spectrum width.

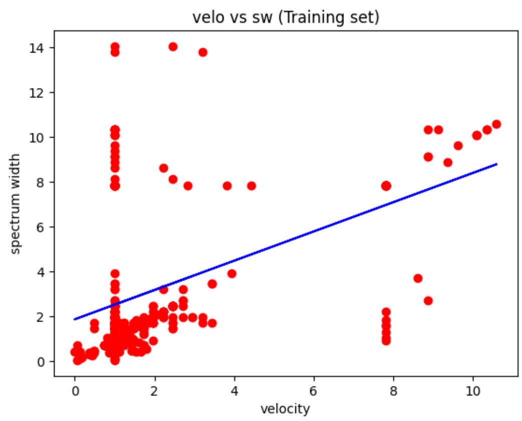

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Figure 4.3 Velocity vs Spectrum Width (Training set)

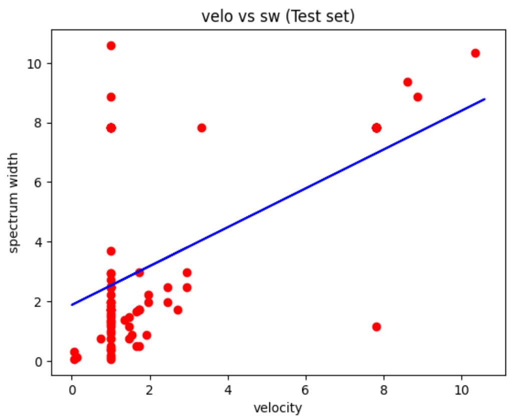

Figure 4.4 Velocity vs Spectrum Width (Test set)

V. CONCLUSION

In conclusion, there is a strong correlation between radar power and reflectivity, with higher power producing a brighter reflected signal and greater sensitivity to targets. To precisely identify and measure targets using radar technology, however, a number of complicated and multifarious aspects that must be properly taken into account and under control must be meticulously correlated.

It is crucial to thoroughly examine the velocity and spectrum width measurements to correctly interpret radar data. In conclusion, radar velocity and spectrum width are connected quantities; nevertheless, their association depends on a variety of variables and requires rigorous analysis in order to properly interpret radar data.

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