ECE 492: Artificial Intelligence Methods ----- Summer 2023

Project 3: Applying Radial Basis Function in Radar Echo Classification

General Background:

Doppler weather radar, such as WSR-88D (NEXRED), is well used in severe weather detection, measurement, and prediction, flash flood warning, tornado detection/prediction, and et. WSR-88D is a power tool used by National Weather Service (NWS). An image of a WSR-88D is as shown in the following figure. You can find such radar in St. Louis too.

Figure. Photo of a WSR-88D radar

Through transmitting and receiving electromagnetic wave, radar can detect target's size, intensity, location, radial velocity, and etc. In radar community, "target" could be classified into two categories: point target (such as airplane, missile, vehicle, etc.), and distributed target (such as cloud, rain, snow, hail). This project is using weather radar to study distributed targets, the precipitation (rain).

Quantitative precipitation estimation (QPE) is one of the key missions of national weather service. Radar meteorologists use radar variables to derive rainfall rate. In the QPE, the most important step is classifying precipitation into either stratiform precipitation type, or convective precipitation type. Generally, stratiform precipitation brings low precipitation rate, you normally see such kind of rain in spring; on the other hand, convective precipitation brings intense precipitation with strong wind, normally comes with thunderstorm.

Radar meteorologists can use the observations from WSR-88D to classify precipitation into either stratiform or convective. In their approaches, four basic radar variables are used, and they are:

1.) reflectivity (Z), a variable measuring the intensity of a radar echo;

2.) differential reflectivity (Z_{DR}), a variable measuring the target's species, shape and orientation;
3.) separation index (I), a variable measuring rain's drop drop size distribution;
4.) reflectivity texture (σ_Z), a variable measuring radar echo's texture.

There are more variables could be directly measured by a Doppler radar, such as Doppler velocity (*V*), differential phase (ϕ_{DP}), correlation coefficient (ρ_{HV}) and etc. In this project we will only use these four variables in radar echo classification.

Project Description:

In this project, we will apply the RBF method to classify precipitation into these two types: stratiform/convective.

Step1: using the provided training data to train the RBF following the example code.
Step2: testing the well-trained RBF with the testing data.

Data:

Training data: Radar data from a WSR-88D radar locates in Taiwan is provide for the training and testing purpose. The training data ("TrainingData.mat") include variables: X_tr [48780, 4] (radar variable), and D [1, 48780] (desired response).
Four variables inside X are: $[I, Z, Z_{DR}, \sigma_Z]$. **Please pay attention on the order**.
For the desired response, D = 1 indicates "convective" type, and D = -1 indicates "stratiform".

Testing data: TestingData.mat could be used to test your result.

Note: training and testing data are with different dimension. When you test the well-trained RBF, you need to convert them into the same dimension.

Project Delivery:

Construct a Radial-Basis Function network to separate convective type from stratiform type.

1.) Shuffled the data.
2.) Set the Epochs as 20.
3.) Selecting all the training data. Using K-mean to cluster them into 10 group (K = 10). Then use the clustering result in the training. **NOTE**: you are welcome to use matlab build in "kmean" command, or write your own "kmean" code.
4.) Repeat step 1 and 2, using 50 (K = 50), and 100 (K = 100). Comparing your results.
5.) Test your training results using **Training data.** Compare the performances from K = 10, 50, and 100. Plot their MSE.
6.) Test your training results using **Testing data.** Compare the performances from K = 10, 50, and 100. Plot their MSE.
7.) Plot four radar variables using the example code
8.) Plot the classification results (K = 10, 50, and 100) using "pcolor" command.

Source code:
You are welcome to use any software/language your preferred. However, no libs, toolboxs, functions related to machine learning are allowed to finish this project. Other mathmatic operation tools, such as matrix multiplication, matrix inverse, convolution, and kmean etc. are welcome to use.

Here is some sample MATLAB code to plot radar variables:

```
pcolor(mat.XPLOT, mat.YPLOT, mat.ZDR_SM);
caxis([-0.5 2]);
shading flat
hh = colorbar;
set(get(hh,'title'),'string','Z_{DR} (dB)');
set(gca, 'FontSize', 16, 'FontWeight', 'bold');
hold on;
axis image
axis([-150 150 -150 150])
grid_on
```

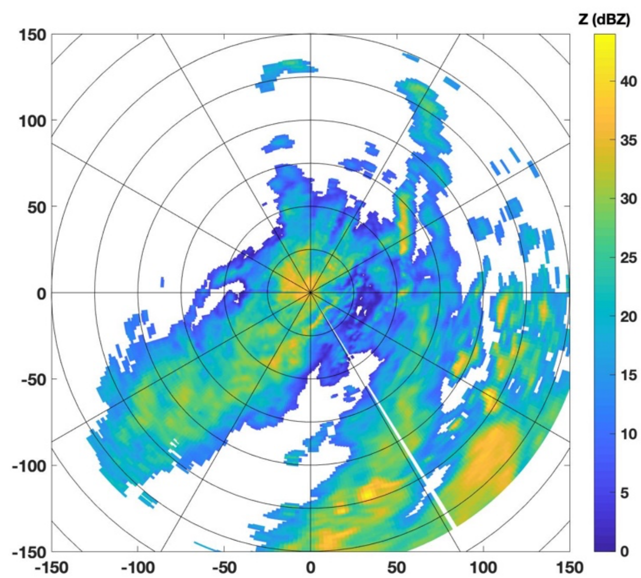

Figure. An example of the radar variable plot:

Report:
A concise report includes: source code, plots, and simple discussion.

Report Due: 06/23/2023
Presentation Due: 06/21/2023

Note: Please let me know by the end of this week if you have any time conflict on your presentation, so we can find a good time for you.
Late submission: 10% per day deduction is applied to any late presentation or report.

Basic requirements for this project: have fun.