Response Spectra Prediction

Using Artificial Neural Network (ANN)

Introduction:

In this study, an ANN was developed to predict Acceleration response spectra with the inputs of:

1. **Earthquake Magnitude**
2. **Hypocentre Depth**
3. **Epicentre Distance**
4. **Shear wave velocity on top 30m of soil surface (Vs30)**

The objective was to establish a reliable predictive framework for estimating response spectra acceleration, which is crucial in seismic hazard analysis and structural engineering applications.

Methodology:

The ANN was trained with nearly 18,700 data points with corresponding Acceleration Response Spectra data points. The following structure was considered to for the model:

- Input layer with 4 neurons corresponding to input features
- **Hidden layers** with neurons
- **Rectified Linear Unit** as activation function in hidden layers
- Output layer predicting Response spectra

XGBoost has been used to fit the model for adjustment of weights.

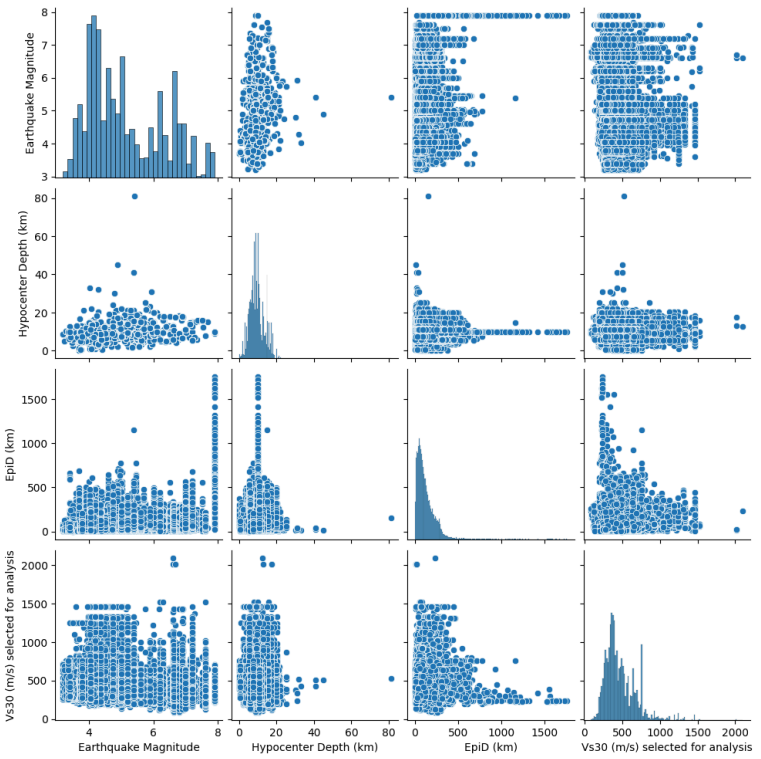
Model performance was modified with following Hperparameters:

- **Number of Hidden Layers**
- **Number of Neurons per layer**
- **Batch Size**

The obtained predicted values were compared to their corresponding original values & **mean absolute error** and **mean squared error** were calculated.
Training over multiple epochs with **batch-wise gradient** updates.

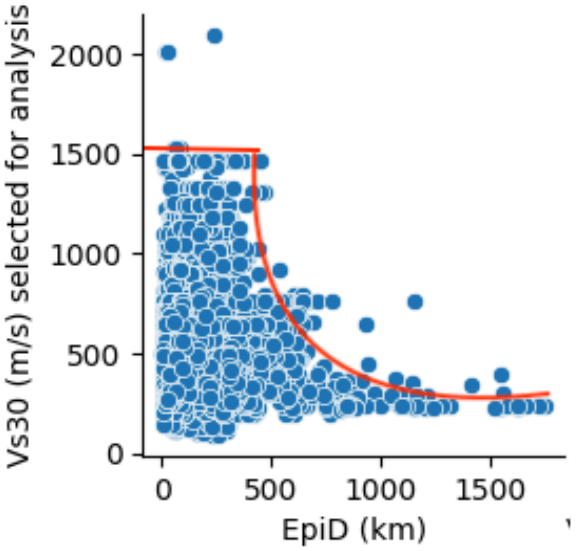
Discussions

Plot of input values to find the correlation between them:



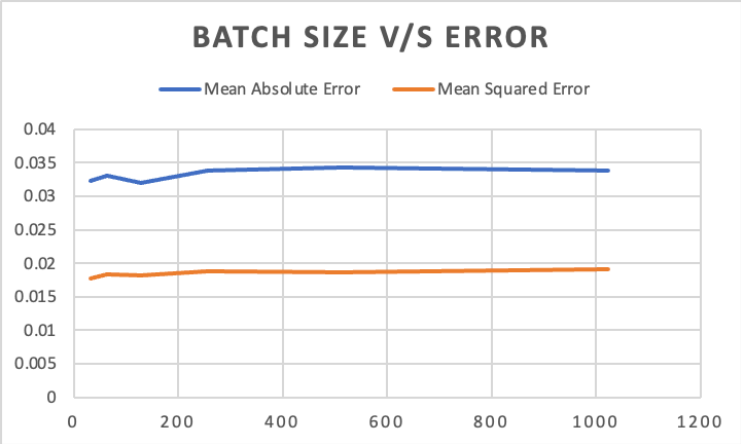
Observations:

1. Magnitude v/s Depth:
   - Most of the Eq's occur at shallow depths & few deep Eq's.
   - **Weak correlation between Magnitude & Depth** as higher magnitudes were occurring at various depths.
2. Magnitude v/s EpiD:
   - Plot shows widespread distribution, indicating some clusters at regions with frequent Eq's
   - **No visibility of linear trends, suggesting direct dependency of both variables**
3. Magnitude v/s Vs30:
   - There are regions where high magnitude correspond to high & low Vs30, suggesting **soil type doesn't affect Eq magnitude**
4. EpiD v/s Depth:
   - Deeper Eq's are found at various EpiD's, suggesting pattern between them
5. EpiD v/s Vs30:
   - We can find a pattern as shown, as **EpiD increases keeps decreasing in a kind of parabolic manner.**
6. Depth v/s Vs30:
   - Plot is quite scattered which says **Vs30 might not be primary factor for controlling depth**



BATCH SIZE

Batch Size	Mean Squared Error	Mean Absolute Error
32	0.017798570055848655	0.03223931703536296
64	0.01837060824732905	0.032996997585248496
128	0.01817495505061514	0.03199783493860837
256	0.01880580599210974	0.033836739046968836
512	0.01871234315649025	0.034234729115433835
1024	0.019063259452607204	0.033862600537886506



The above obtained data is for relu activation function with 2 Hidden layers at 10 units per layer.

- On running the ANN (with 10 units in each layer & 2 Hidden layers) with multiple batch sizes, the error observed was least at batch size = 128.
- Thus, **Optimal batch size is set to 128**

- Number of **Epoch are fixed to 200** throughout the ANN model, which was found to be optimal after some research
- The Activation function used are (for single hidden layer):

ACTIVATION FUNCTION USED	BEST ACCURACY OBSERVED
Rectified Linear Unit (relu)	45.83 (7 neurons)
Leaky Rectified Linear Unit (leaky relu)	50.39 (7 neurons)
Sigmoid	47.21 (8 neurons)
Exponential linear unit (ELU)	46.94 (8 neurons)

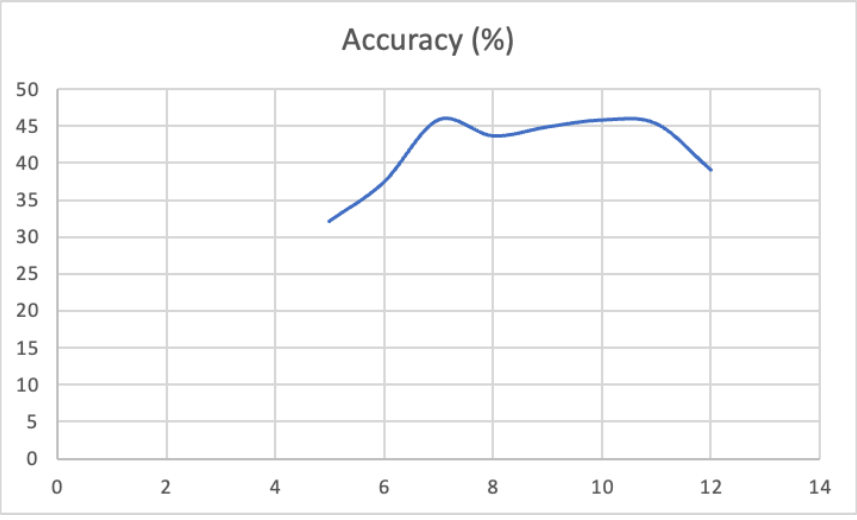
NUMBER OF NEURONS

Per each hidden layer

- No.of estimators used in XGBoost = 100 at a learning rate = 0.1.
- We fix the no. of hidden layers to be one, once the no. of optimal neurons per layer are obtained, Optimum Hidden layers will be scaled accordingly.
- First we trail with no.of neurons from 5, 6, 7, 8, 9, 10, 11, 12. Above which accuracy drops drastically. Below is the data for single hidden layer, activation function = relu

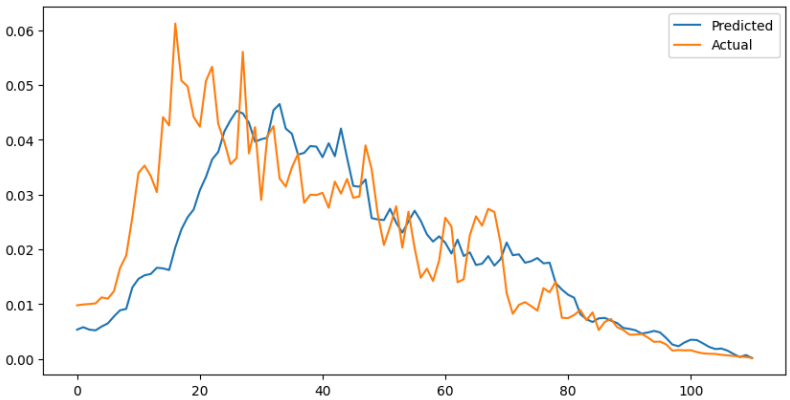
No.of Neurons	Accuracy (%)
5	32.06
6	37.35
7	45.83
8	43.66
9	44.87
10	45.81
11	45.31
12	39.03

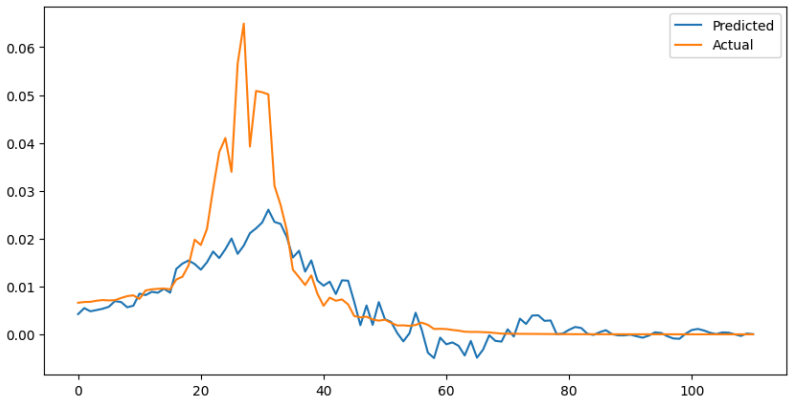
- Clearly **optimal no.of neurons = 7 or 10**

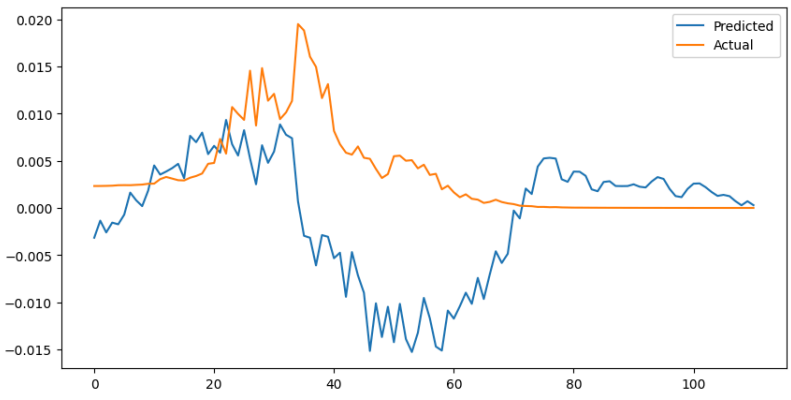


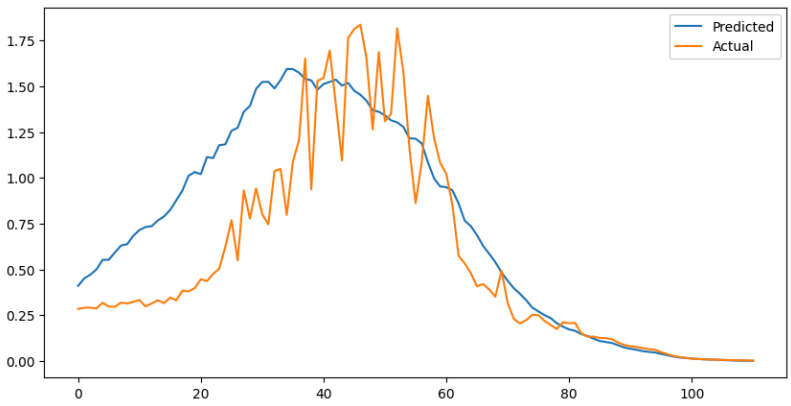
NUMBER OF HIDDEN LAYERS

- After multiple iterations of different layers we found 10 layers at 3 Hidden Layers was optimal.
- Below are few predicted graphs of the ANN model:









CONCLUSION:

1. **ACTIVATION FUNCTION = LEAKY RECTIFIED LINEAR UNIT**
2. **NUMBER OF NEURON UNITS IN EACH LAYER = 10**
3. **NUMBER OF HIDDEN LAYERS = 3**
4. **BATCH SIZE = 128**
5. **EPOCHS = 200**

CODE: **ANN.ipynb**

THANK YOU