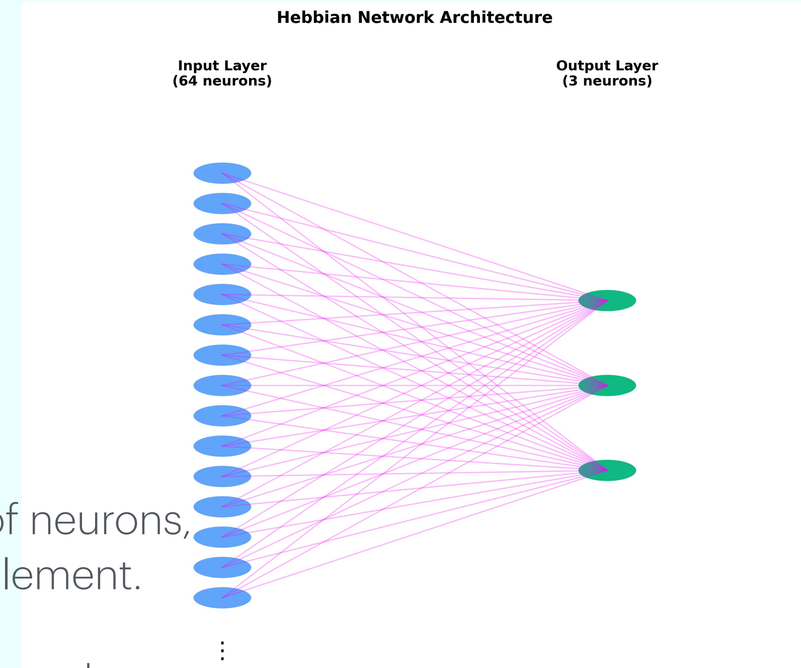
Final Project - Introduction to Neuroscience

The Hebbian Network- information and implementation

Authors:
Itay Segev, Salome Timsit

Hebbian Network Information

Introduction to Hebbian Network



- The Hebbian network is a simple neuron network, who has 2 layers of neurons, the input layer and the output layer. What makes it more easy to implement.

- In the Hebbian network there is more weight for 2 neurons that fire together, “cells that fire together wire together”, that means that two neurons who activate together
  will have more strength.

- The Hebbian Network demonstrate the quote from the last dot,
  it also increase each synaptic cells between 2 neurons who work together in the input layer and the output layer.

Hebbian Network Information

Theoretical Principles

- **Associative learning -** If neuron A activates neuron B over and over again, the connection the connection between those two will get stronger.

- **Synaptic Plasticity-** The theory describe how synapse changes and strengthen in response to coordinated activity.

- **Cell Assembly Theory-** Hebbian wrote about the connection between groups of neurons and their ability to create patterns and group them together
  on his words: “When one cell repeatedly assists in firing another, the axon of the first cell develops synaptic knobs (or enlarges them if they already exist) in contact with the soma of the second cell.”

Hebbian Network Information

Pros of Hebbian Network

✓ **Biological Plausibility -** The Hebbian learning rule is mirroring to our biological neurons and making it more understandable the connection between the neurons.

✓ **Easy Implementation -** The Hebbian Network is not hard for implementation and it makes the network easier to understand the connections between the neurons, and with good odds of success.

✓ **Flexibility-** The Hebbian networks are flexibility and they can adjust themself to a new data and environment dynamically.

✓ **Pattern Recognition-** This capability is crucial for sensory process and classification tasks.

Hebbian Network Information

Cons of Hebbian Network

X Unbounded Synapse Growth- The synapse can growth without bond, what can makes the network to bu unstable, if the weights font get normalization.

X Sensitive to Noise- The noise in the input data can lead to false associations or poor generalization.

X Tendency to Overfitting- The hebbian network has tendency to overfitting what can makes difficulties by trying to give a new input data, that the network never seen

X Vulnerably Forgetting- When the Hebbian Network training on new given data it can forget all the synaptic memory.

Hebbian Network Information

Algorithm of Hebbian Network

Basic Rule: $\mathbf{W}^{new} = \mathbf{W}^{old} + \mathbf{t}_q \mathbf{p}_q^T$

Learning Rate: $\mathbf{W}^{new} = \mathbf{W}^{old} + \alpha \mathbf{t}_q \mathbf{p}_q^T$

Smoothing: $\mathbf{W}^{new} = \mathbf{W}^{old} + \alpha \mathbf{t}_q \mathbf{p}_q^T - \gamma \mathbf{W}^{old} = (1-\gamma)\mathbf{W}^{old} + \alpha \mathbf{t}_q \mathbf{p}_q^T$

Delta Rule: $\mathbf{W}^{new} = \mathbf{W}^{old} + \alpha(\mathbf{t}_q - \mathbf{a}_q)\mathbf{p}_q^T$

Unsupervised: $\mathbf{W}^{new} = \mathbf{W}^{old} + \alpha \mathbf{a}_q \mathbf{p}_q^T$

The Hebbian Network have a specific learning algorithm based on the updating weights mechanism. In this Algorithm there is a formula for updating the weights.

- At first the Delta of the weight will be calculated:
  $\Delta w(i,j) = \eta \cdot (t(i)-y(i)) \cdot x(j)$ - The delta weight calculated by
  Learning rate * (target output - really output) * the input

- Secondly the real weight will be affected by the delta that calculated and the real weight
  for dealing with the unbounded synapse growth, there is an a regularization to prevent it:
  $w(i,j)+ = \eta \cdot (t(i)-y(i)) \cdot x(j) - \lambda w(i,j) = \Delta w(i,j) - \lambda w(i,j)$
  The explanation is that there is a regularization variable the prevent this problem and make the growth be normalized.

Hebbian Network Implementation

First Review On Our Program-Training

- At first we build a raw net, by giving it the size of it, the learning rate we want, and setup all the weights to 0.

- Secondly we started to train our network given all the input train and their targets.
  in this part we got how many epochs the user want to do and for each epoch we calculated the total error by calculating the distance of each calculating from the target.
  For each output we use the sigmoid function that normalized the calculation.

- Thirdly, we calculating the new weights. And after all the 26 inputs we check if the total error is good enough, if it was better then the last epoch we will save the results. And print data after each 10 epochs.

Hebbian Network Implementation

First Review On Our Program-Training and Prediction

- After all the epochs or when we succeed to getting to converge we take the best weights with the less total errors and replace the weight mat by this mat.

  And here is the Finished training our network with the given inputs and we can start try give the net inputs it never seen and try to predict their answers.

- On the predict Method it will calculate by the weights all the 3 outputs and return a vector the represent the group this letter is belong

Hebbian Network Implementation

First Review On Our Program-accuracy

- After we trained our network and check for each letter their predict, we want to start calculating the accuracy per each test group.

  The calculation is by calculate the number of times the network succeeded for prediction.

- After calculating we can assume the accuracy per each new group.

Hebbian Network Implementation

First Review On Our Program-accuracy

- We assumed that it is not enough to calculate the accuracy per each group (of the random percent of mistakes) cause each group looks a little different, so per each mistake from we calculated the accuracy for one group in one run, and for 500 times.

Hebbian Network Implementation

Result of our Program- The train data

- If the network succeeded by the train, for the train data the network should succeed doing 100% of success.

```
the accuracy with Group of the train letters : 100.00%
Results for this group:
    The letter A Suppose to be in: A-I,and the answer is: A-I
    The letter B Suppose to be in: A-I,and the answer is: A-I
    The letter C Suppose to be in: A-I,and the answer is: A-I
    The letter D Suppose to be in: A-I,and the answer is: A-I
    The letter E Suppose to be in: A-I,and the answer is: A-I
    The letter F Suppose to be in: A-I,and the answer is: A-I
    The letter G Suppose to be in: A-I,and the answer is: A-I
    The letter H Suppose to be in: A-I,and the answer is: A-I
    The letter I Suppose to be in: A-I,and the answer is: A-I
    The letter J Suppose to be in: J-R,and the answer is: J-R
    The letter K Suppose to be in: J-R,and the answer is: J-R
    The letter L Suppose to be in: J-R,and the answer is: J-R
    The letter M Suppose to be in: J-R,and the answer is: J-R
    The letter N Suppose to be in: J-R,and the answer is: J-R
    The letter O Suppose to be in: J-R,and the answer is: J-R
    The letter P Suppose to be in: J-R,and the answer is: J-R
    The letter Q Suppose to be in: J-R,and the answer is: J-R
    The letter R Suppose to be in: J-R,and the answer is: J-R
    The letter S Suppose to be in: S-Z,and the answer is: S-Z
    The letter T Suppose to be in: S-Z,and the answer is: S-Z
    The letter U Suppose to be in: S-Z,and the answer is: S-Z
    The letter V Suppose to be in: S-Z,and the answer is: S-Z
    The letter W Suppose to be in: S-Z,and the answer is: S-Z
    The letter X Suppose to be in: S-Z,and the answer is: S-Z
    The letter Y Suppose to be in: S-Z,and the answer is: S-Z
    The letter Z Suppose to be in: S-Z,and the answer is: S-Z
```

Hebbian Network Implementation

Result of our Program- Noise Data

✦Here we going to see the results for the Noise Data groups.

```
the accuracy with Group with 5% of mistakes : 96.15%
Results for this group:
    The letter A Suppose to be in: A-I,and the answer is: A-I
    The letter B Suppose to be in: A-I,and the answer is: A-I
    The letter C Suppose to be in: A-I,and the answer is: A-I
    The letter D Suppose to be in: A-I,and the answer is: A-I
    The letter E Suppose to be in: A-I,and the answer is: A-I
    The letter F Suppose to be in: A-I,and the answer is: A-I
    The letter G Suppose to be in: A-I,and the answer is: A-I
    The letter H Suppose to be in: A-I,and the answer is: A-I
    The letter I Suppose to be in: A-I,and the answer is: S-Z
    The letter J Suppose to be in: J-R,and the answer is: J-R
    The letter K Suppose to be in: J-R,and the answer is: J-R
    The letter L Suppose to be in: J-R,and the answer is: J-R
    The letter M Suppose to be in: J-R,and the answer is: J-R
    The letter N Suppose to be in: J-R,and the answer is: J-R
    The letter O Suppose to be in: J-R,and the answer is: J-R
    The letter P Suppose to be in: J-R,and the answer is: J-R
    The letter Q Suppose to be in: J-R,and the answer is: J-R
    The letter R Suppose to be in: J-R,and the answer is: J-R
    The letter S Suppose to be in: S-Z,and the answer is: S-Z
    The letter T Suppose to be in: S-Z,and the answer is: S-Z
    The letter U Suppose to be in: S-Z,and the answer is: S-Z
    The letter V Suppose to be in: S-Z,and the answer is: S-Z
    The letter W Suppose to be in: S-Z,and the answer is: S-Z
    The letter X Suppose to be in: S-Z,and the answer is: S-Z
    The letter Y Suppose to be in: S-Z,and the answer is: S-Z
    The letter Z Suppose to be in: S-Z,and the answer is: S-Z
```

```
the accuracy with Group with 10% of mistakes : 88.46%
Results for this group:
    The letter A Suppose to be in: A-I,and the answer is: A-I
    The letter B Suppose to be in: A-I,and the answer is: A-I
    The letter C Suppose to be in: A-I,and the answer is: A-I
    The letter D Suppose to be in: A-I,and the answer is: A-I
    The letter E Suppose to be in: A-I,and the answer is: J-R
    The letter F Suppose to be in: A-I,and the answer is: S-Z
    The letter G Suppose to be in: A-I,and the answer is: A-I
    The letter H Suppose to be in: A-I,and the answer is: A-I
    The letter I Suppose to be in: A-I,and the answer is: A-I
    The letter J Suppose to be in: J-R,and the answer is: J-R
    The letter K Suppose to be in: J-R,and the answer is: J-R
    The letter L Suppose to be in: J-R,and the answer is: J-R
    The letter M Suppose to be in: J-R,and the answer is: J-R
    The letter N Suppose to be in: J-R,and the answer is: J-R
    The letter O Suppose to be in: J-R,and the answer is: J-R
    The letter P Suppose to be in: J-R,and the answer is: J-R
    The letter Q Suppose to be in: J-R,and the answer is: J-R
    The letter R Suppose to be in: J-R,and the answer is: J-R
    The letter S Suppose to be in: S-Z,and the answer is: S-Z
    The letter T Suppose to be in: S-Z,and the answer is: S-Z
    The letter U Suppose to be in: S-Z,and the answer is: S-Z
    The letter V Suppose to be in: S-Z,and the answer is: S-Z
    The letter W Suppose to be in: S-Z,and the answer is: S-Z
    The letter X Suppose to be in: S-Z,and the answer is: S-Z
    The letter Y Suppose to be in: S-Z,and the answer is: A-I
    The letter Z Suppose to be in: S-Z,and the answer is: S-Z
```

```
the accuracy with 15% of mistake is: 80.77%
Results for this group:
    The letter A Suppose to be in: A-I,and the answer is: A-I
    The letter B Suppose to be in: A-I,and the answer is: S-Z
    The letter C Suppose to be in: A-I,and the answer is: A-I
    The letter D Suppose to be in: A-I,and the answer is: A-I
    The letter E Suppose to be in: A-I,and the answer is: J-R
    The letter F Suppose to be in: A-I,and the answer is: A-I
    The letter G Suppose to be in: A-I,and the answer is: A-I
    The letter H Suppose to be in: A-I,and the answer is: A-I
    The letter I Suppose to be in: A-I,and the answer is: A-I
    The letter J Suppose to be in: J-R,and the answer is: J-R
    The letter K Suppose to be in: J-R,and the answer is: J-R
    The letter L Suppose to be in: J-R,and the answer is: S-Z
    The letter M Suppose to be in: J-R,and the answer is: J-R
    The letter N Suppose to be in: J-R,and the answer is: S-Z
    The letter O Suppose to be in: J-R,and the answer is: A-I
    The letter P Suppose to be in: J-R,and the answer is: J-R
    The letter Q Suppose to be in: J-R,and the answer is: J-R
    The letter R Suppose to be in: J-R,and the answer is: J-R
    The letter S Suppose to be in: S-Z,and the answer is: S-Z
    The letter T Suppose to be in: S-Z,and the answer is: S-Z
    The letter U Suppose to be in: S-Z,and the answer is: S-Z
    The letter V Suppose to be in: S-Z,and the answer is: S-Z
    The letter W Suppose to be in: S-Z,and the answer is: S-Z
    The letter X Suppose to be in: S-Z,and the answer is: S-Z
    The letter Y Suppose to be in: S-Z,and the answer is: S-Z
    The letter Z Suppose to be in: S-Z,and the answer is: S-Z
```

```
the accuracy with Group with 20% of mistakes : 73.08%
Results for this group:
    The letter A Suppose to be in: A-I,and the answer is: A-I
    The letter B Suppose to be in: A-I,and the answer is: J-R
    The letter C Suppose to be in: A-I,and the answer is: A-I
    The letter D Suppose to be in: A-I,and the answer is: A-I
    The letter E Suppose to be in: A-I,and the answer is: A-I
    The letter F Suppose to be in: A-I,and the answer is: A-I
    The letter G Suppose to be in: A-I,and the answer is: A-I
    The letter H Suppose to be in: A-I,and the answer is: A-I
    The letter I Suppose to be in: A-I,and the answer is: S-Z
    The letter J Suppose to be in: J-R,and the answer is: J-R
    The letter K Suppose to be in: J-R,and the answer is: A-I
    The letter L Suppose to be in: J-R,and the answer is: S-Z
    The letter M Suppose to be in: J-R,and the answer is: J-R
    The letter N Suppose to be in: J-R,and the answer is: J-R
    The letter O Suppose to be in: J-R,and the answer is: J-R
    The letter P Suppose to be in: J-R,and the answer is: A-I
    The letter Q Suppose to be in: J-R,and the answer is: J-R
    The letter R Suppose to be in: J-R,and the answer is: J-R
    The letter S Suppose to be in: S-Z,and the answer is: S-Z
    The letter T Suppose to be in: S-Z,and the answer is: A-I
    The letter U Suppose to be in: S-Z,and the answer is: S-Z
    The letter V Suppose to be in: S-Z,and the answer is: S-Z
    The letter W Suppose to be in: S-Z,and the answer is: S-Z
    The letter X Suppose to be in: S-Z,and the answer is: S-Z
    The letter Y Suppose to be in: S-Z,and the answer is: S-Z
    The letter Z Suppose to be in: S-Z,and the answer is: J-R
```

Hebbian Network Implementation

Result on our Program- Noise Data

- As we said before on the noise data we calculated the mean of 500 runs of the accuracy on the same percent of noise but other vectors, and we also calculated the variance and the standard deviation of the mistakes.

```
calculating of accuracy in avarage on 500 times of running
the average accuracy on 500 loops with 5% of mistake is: 94.08%
The variance of the 5% mistake is: 0.22%
The standard deviation of the 5% mistake is: 4.69%

the average accuracy on 500 loops with 10% of mistake is: 83.86%
The variance of the 10% mistake is: 0.50%
The standard deviation of the 10% mistake is: 7.05%

the average accuracy on 500 loops with 15% of mistake is: 74.64%
The variance of the 15% mistake is: 0.67%
The standard deviation of the 15% mistake is: 8.21%

the average accuracy on 500 loops with 20% of mistake is: 67.61%
The variance of the 20% mistake is: 0.79%
The standard deviation of the 20% mistake is: 8.88%
```

Hebbian Network Implementation

Result of our Program- New letters groups

- For testing our network on new groups of data we made 3 new groups of data:
  1.Bold Letters **2.**Bold and circle Letters **3.** Extra Bold an circle Letters
  As we predicted the accuracy wasn't really good but this is one of the cons for that network.

```
the accuracy with Group 1:Bold : 57.69%
Results for this group:
    The letter A Suppose to be in: A-I,and the answer is: A-I
    The letter B Suppose to be in: A-I,and the answer is: A-I
    The letter C Suppose to be in: A-I,and the answer is: J-R
    The letter D Suppose to be in: A-I,and the answer is: J-R
    The letter E Suppose to be in: A-I,and the answer is: A-I
    The letter F Suppose to be in: A-I,and the answer is: A-I
    The letter G Suppose to be in: A-I,and the answer is: A-I
    The letter H Suppose to be in: A-I,and the answer is: A-I
    The letter I Suppose to be in: A-I,and the answer is: S-Z
    The letter J Suppose to be in: J-R,and the answer is: A-I
    The letter K Suppose to be in: J-R,and the answer is: J-R
    The letter L Suppose to be in: J-R,and the answer is: J-R
    The letter M Suppose to be in: J-R,and the answer is: J-R
    The letter N Suppose to be in: J-R,and the answer is: J-R
    The letter O Suppose to be in: J-R,and the answer is: A-I
    The letter P Suppose to be in: J-R,and the answer is: A-I
    The letter Q Suppose to be in: J-R,and the answer is: J-R
    The letter R Suppose to be in: J-R,and the answer is: J-R
    The letter S Suppose to be in: S-Z,and the answer is: A-I
    The letter T Suppose to be in: S-Z,and the answer is: S-Z
    The letter U Suppose to be in: S-Z,and the answer is: A-I
    The letter V Suppose to be in: S-Z,and the answer is: S-Z
    The letter W Suppose to be in: S-Z,and the answer is: J-R
    The letter X Suppose to be in: S-Z,and the answer is: J-R
    The letter Y Suppose to be in: S-Z,and the answer is: S-Z
    The letter Z Suppose to be in: S-Z,and the answer is: J-R
```

```
the accuracy with Group 2:Bold and circle : 65.38%
Results for this group:
    The letter A Suppose to be in: A-I,and the answer is: A-I
    The letter B Suppose to be in: A-I,and the answer is: A-I
    The letter C Suppose to be in: A-I,and the answer is: A-I
    The letter D Suppose to be in: A-I,and the answer is: A-I
    The letter E Suppose to be in: A-I,and the answer is: A-I
    The letter F Suppose to be in: A-I,and the answer is: A-I
    The letter G Suppose to be in: A-I,and the answer is: A-I
    The letter H Suppose to be in: A-I,and the answer is: A-I
    The letter I Suppose to be in: A-I,and the answer is: A-I
    The letter J Suppose to be in: J-R,and the answer is: A-I
    The letter K Suppose to be in: J-R,and the answer is: J-R
    The letter L Suppose to be in: J-R,and the answer is: J-R
    The letter M Suppose to be in: J-R,and the answer is: J-R
    The letter N Suppose to be in: J-R,and the answer is: J-R
    The letter O Suppose to be in: J-R,and the answer is: A-I
    The letter P Suppose to be in: J-R,and the answer is: J-R
    The letter Q Suppose to be in: J-R,and the answer is: A-I
    The letter R Suppose to be in: J-R,and the answer is: J-R
    The letter S Suppose to be in: S-Z,and the answer is: A-I
    The letter T Suppose to be in: S-Z,and the answer is: S-Z
    The letter U Suppose to be in: S-Z,and the answer is: A-I
    The letter V Suppose to be in: S-Z,and the answer is: J-R
    The letter W Suppose to be in: S-Z,and the answer is: J-R
    The letter X Suppose to be in: S-Z,and the answer is: J-R
    The letter Y Suppose to be in: S-Z,and the answer is: J-R
    The letter Z Suppose to be in: S-Z,and the answer is: S-Z
```

```
the accuracy with Group 3:extra Bold and circle : 53.85%
Results for this group:
    The letter A Suppose to be in: A-I,and the answer is: A-I
    The letter B Suppose to be in: A-I,and the answer is: A-I
    The letter C Suppose to be in: A-I,and the answer is: A-I
    The letter D Suppose to be in: A-I,and the answer is: J-R
    The letter E Suppose to be in: A-I,and the answer is: J-R
    The letter F Suppose to be in: A-I,and the answer is: A-I
    The letter G Suppose to be in: A-I,and the answer is: A-I
    The letter H Suppose to be in: A-I,and the answer is: J-R
    The letter I Suppose to be in: A-I,and the answer is: J-R
    The letter J Suppose to be in: J-R,and the answer is: A-I
    The letter K Suppose to be in: J-R,and the answer is: J-R
    The letter L Suppose to be in: J-R,and the answer is: J-R
    The letter M Suppose to be in: J-R,and the answer is: J-R
    The letter N Suppose to be in: J-R,and the answer is: J-R
    The letter O Suppose to be in: J-R,and the answer is: A-I
    The letter P Suppose to be in: J-R,and the answer is: J-R
    The letter Q Suppose to be in: J-R,and the answer is: J-R
    The letter R Suppose to be in: J-R,and the answer is: J-R
    The letter S Suppose to be in: S-Z,and the answer is: A-I
    The letter T Suppose to be in: S-Z,and the answer is: J-R
    The letter U Suppose to be in: S-Z,and the answer is: A-I
    The letter V Suppose to be in: S-Z,and the answer is: J-R
    The letter W Suppose to be in: S-Z,and the answer is: S-Z
    The letter X Suppose to be in: S-Z,and the answer is: J-R
    The letter Y Suppose to be in: S-Z,and the answer is: J-R
    The letter Z Suppose to be in: S-Z,and the answer is: S-Z
```

Hebbian Network Implementation

Summery of Our program

- As you can see on the results the accuracy for noise is pretty good:
  94% for 5% noise, 83% for 10% noise, 74% for 15% noise, 67% for 20% noise

- The accuracy of the new letters group weren’t that good, as expected, but still it succeeded to classify more than 50% of the letters, and one group succeeded to predict 67% of the letters.

Hebbian Network Summery

Summery of Our program

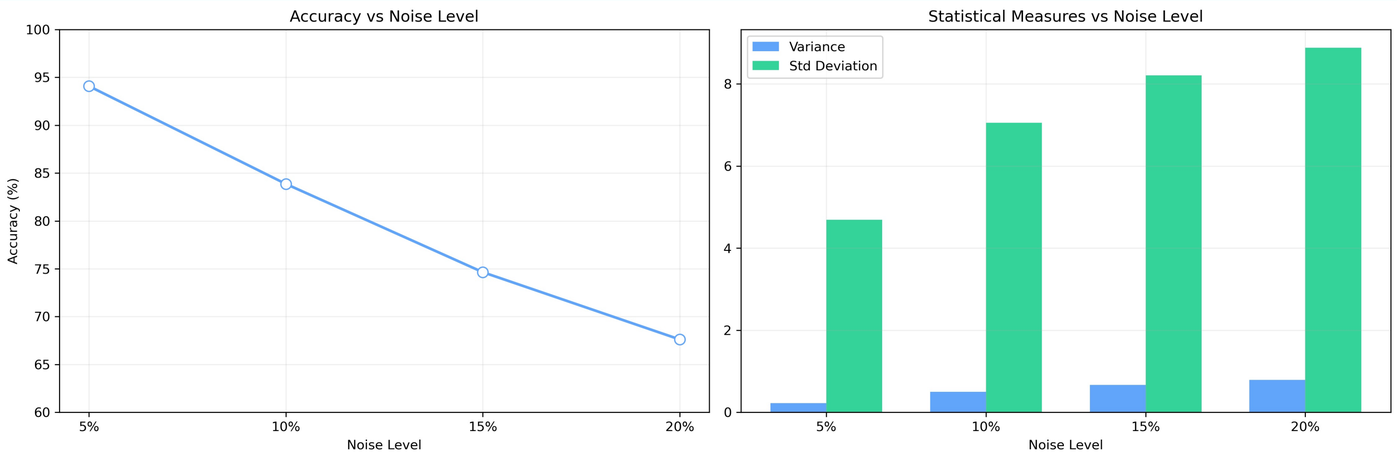
- The Hebbian Network is the perfect middle between learning networks and easy implementation

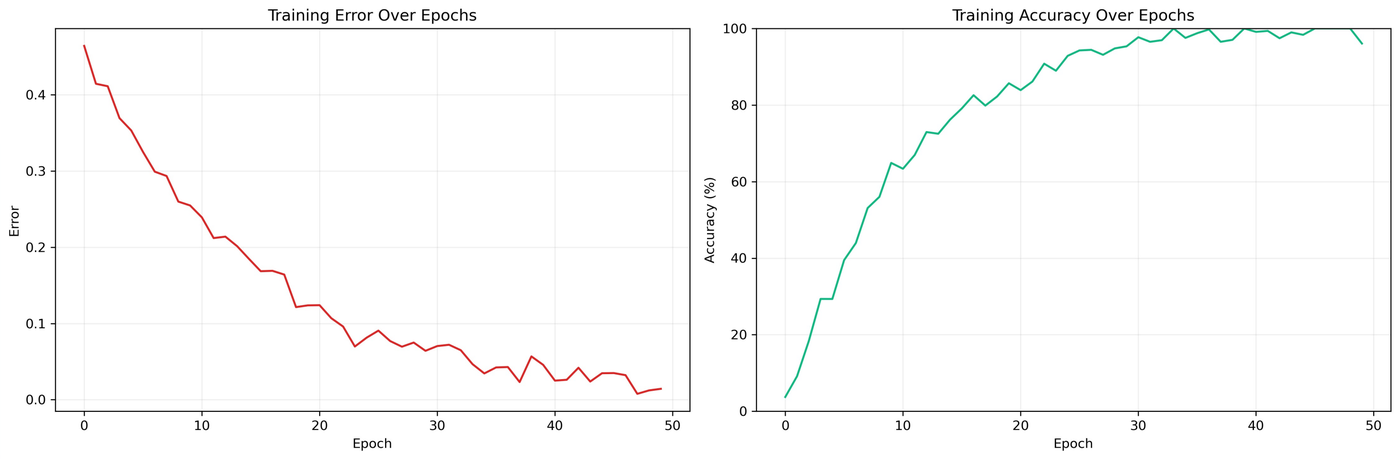
- Hebbian Network predicts noisy input till 10% really good.
  Although the network has only 2 layers it handles pretty good with noisy data.

- The Hebbian Network not fit and is not a good choice for unseen data.

Hebbian Network Summery

Analysis





Hebbian Network Summery

Next Question That can be Explored

? If it will be trained by more than 1 set of letters it will give better results or less accurate results?

? How we can take this Hebbian Network and implement its principle in more complex Networks?

? If there is another layer that calculated the important and less important neurons the Network will improved?

Hebbian Network Summery

Bibliography

- What is Hebbian Learning
- How neurons wire together
- Hebbian learning - the desicion lab
- Hebbian learning- geeks for geeks
- Hebbian Theory -Wikipedia
- Semanticscholar
- SlidePlayer- Hebbian
- Hebbian Algorithm video - Youtube

THANK YOU FOR LISTENING