**Problem Statement**

Create a Double Layer Neural Network to solve multi-class identification problem and analyse the use of various activation functions with different number of hidden layers and iterations per layer.

**Data Set**

We have selected a **Wine Recognition Dataset**. This dataset is the result of the chemical analysis of wines grown in the same region in Italy by three different cultivators. There are thirteen different measurements taken for different constituents found in the three types of wine.

**Attributes:**

* Alcohol
* Malic Acid
* Ash
* Alcalinity of Ash
* Magnesium
* Total Phenols
* Flavanoids
* Non-flavanoid Phenols
* Proanthocyanins
* Color intensity
* Hue
* OD280/OD315 of Diluted Wines
* Proline

**Class Distribution:**

* Class 0 (59 examples)
* Class 1 (71 examples)
* Class 2 (48 examples)

**Approach:**

We have merged class 0 and class 2 together into class 0. We then use our both Single & Double Layer Neural Network Code to predict the two classes and calculate the accuracy and cost of the network for the model.

**Output:**

**Combination 1:** TANH, SIGMOID *(Single Layer)*

|  |  |  |  |
| --- | --- | --- | --- |
| **No. of Iterations** | **Hidden Layer** | **Accuracy** | **Cost Value** |
| 5000 | 1 | 100.00% | 273.8164508 |
|  | 2 | 100.00% | 254.1498229 |
|  | 3 | 100.00% | 240.255863 |
|  | 4 | 100.00% | 245.1046094 |
|  | 5 | 100.00% | 234.0943796 |
|  |  |  |  |
| 10000 | 1 | 100.00% | 289.274654 |
|  | 2 | 100.00% | 269.6323777 |
|  | 3 | 100.00% | 255.6860426 |
|  | 4 | 100.00% | 260.6392838 |
|  | 5 | 100.00% | 249.5681253 |
|  |  |  |  |
| 20000 | 1 | 100.00% | 302.8651074 |
|  | 2 | 100.00% | 283.0817052 |
|  | 3 | 100.00% | 269.1355056 |
|  | 4 | 100.00% | 274.0239649 |
|  | 5 | 100.00% | 262.9212276 |

**Combination 2:** RELU, SIGMOID *(Single Layer)*

|  |  |  |  |
| --- | --- | --- | --- |
| **No. of Iterations** | **Hidden Layer** | **Accuracy** | **Cost Value** |
| 5000 | 1 | 61.00% | 3335.340834 |
|  | 2 | 100.00% | 529.5713572 |
|  | 3 | 98.00% | 817.3897909 |
|  | 4 | 99.00% | 909.0165812 |
|  | 5 | 100.00% | 504.8835762 |
|  |  |  |  |
| 10000 | 1 | 61.00% |  |
|  | 2 | 100.00% | nan |
|  | 3 | 100.00% | 564.5235387 |
|  | 4 | 100.00% | 874.4522254 |
|  | 5 | 100.00% | 954.2712143 |
|  |  |  |  |
| 20000 | 1 | 61.00% | 538.8362641 |
|  | 2 | 100.00% |  |
|  | 3 | 100.00% | nan |
|  | 4 | 100.00% | 592.4580296 |
|  | 5 | 100.00% | 898.7896821 |

**Combination 3:** TANH, TANH, SIGMOID *(Double Layer)*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **No. of Iterations** | **Hidden Layer 1** | **Hidden Layer 2** | **Accuracy** | **Cost Value** |
| 5000 | 1 | 1 | 60.00% | 3362.981553 |
|  | 2 | 1 | 98.00% | 3315.462624 |
|  | 2 | 2 | 60.00% | 3362.981288 |
|  | 3 | 1 | 60.00% | 3362.979948 |
|  | 3 | 2 | 60.00% | 3362.981374 |
|  | 3 | 3 | 60.00% | 3362.975878 |
|  | 4 | 1 | 60.00% | 3362.980516 |
|  | 4 | 2 | 60.00% | 3362.980994 |
|  | 4 | 3 | 100.00% | 2864.013001 |
|  | 4 | 4 | 60.00% | 3362.980538 |
|  |  |  |  |  |
| 10000 | 1 | 1 | 60.00% | 6724.950819 |
|  | 2 | 1 | 100.00% | 3346.683339 |
|  | 2 | 2 | 100.00% | 5070.997163 |
|  | 3 | 1 | 100.00% | 4320.974081 |
|  | 3 | 2 | 100.00% | 5268.870046 |
|  | 3 | 3 | 100.00% | 3897.831319 |
|  | 4 | 1 | 100.00% | 4529.262106 |
|  | 4 | 2 | 100.00% | 4875.087756 |
|  | 4 | 3 | 100.00% | 2872.667693 |
|  | 4 | 4 | 100.00% | 4495.278411 |
|  |  |  |  |  |
| 20000 | 1 | 1 | 100.00% | 6810.749745 |
|  | 2 | 1 | 100.00% | 3352.569805 |
|  | 2 | 2 | 100.00% | 5076.570754 |
|  | 3 | 1 | 100.00% | 4328.246246 |
|  | 3 | 2 | 100.00% | 5275.579845 |
|  | 3 | 3 | 100.00% | 3901.306867 |
|  | 4 | 1 | 100.00% | 4536.933134 |
|  | 4 | 2 | 100.00% | 4536.933134 |
|  | 4 | 3 | 100.00% | 2875.803119 |
|  | 4 | 4 | 100.00% | 4499.077953 |

**Combination 4:** TANH, RELU, SIGMOID *(Double Layer)*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **No. of Iterations** | **Hidden Layer 1** | **Hidden Layer 2** | **Accuracy** | **Cost Value** |
| 5000 | 1 | 1 | 60.00% | 3362.9816 |
|  | 2 | 1 | 92.00% | 3333.1958 |
|  | 2 | 2 | 60.00% | 3362.9813 |
|  | 3 | 1 | 60.00% | 3362.9799 |
|  | 3 | 2 | 60.00% | 3362.9816 |
|  | 3 | 3 | 60.00% | 3362.9816 |
|  | 4 | 1 | 60.00% | 3362.9805 |
|  | 4 | 2 | 60.00% | 3362.981 |
|  | 4 | 3 | 100.00% | 2900.0604 |
|  | 4 | 4 | 60.00% | 3362.9811 |
|  |  |  |  |  |
| 10000 | 1 | 1 | 60.00% | 6725.7489 |
|  | 2 | 1 | 100.00% | 3391.589 |
|  | 2 | 2 | 100.00% | 5199.9893 |
|  | 3 | 1 | 100.00% | 4368.8396 |
|  | 3 | 2 | 60.00% | 6725.7487 |
|  | 3 | 3 | 100.00% | 6502.2877 |
|  | 4 | 1 | 100.00% | 4597.0653 |
|  | 4 | 2 | 100.00% | 4945.6164 |
|  | 4 | 3 | 100.00% | 2905.6252 |
|  | 4 | 4 | 100.00% | 5041.7686 |
|  |  |  |  |  |
| 20000 | 1 | 1 | 60.00% | 13451.283 |
|  | 2 | 1 | 100.00% | 3398.8121 |
|  | 2 | 2 | 100.00% | 5203.8353 |
|  | 3 | 1 | 100.00% | 4377.7381 |
|  | 3 | 2 | 100.00% | nan |
|  | 3 | 3 | 100.00% | 6511.5179 |
|  | 4 | 1 | 100.00% | 4609.5418 |
|  | 4 | 2 | 100.00% | 4956.754 |
|  | 4 | 3 | 100.00% | 2906.9694 |
|  | 4 | 4 | 100.00% | 5045.1732 |

**Combination 5:** RELU, RELU, SIGMOID *(Double Layer)*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **No. of Iterations** | **Hidden Layer 1** | **Hidden Layer 2** | **Accuracy** | **Cost Value** |
| 5000 | 1 | 1 | 60.00% | 3362.981583 |
|  | 2 | 1 | 60.00% | 3362.981562 |
|  | 2 | 2 | 60.00% | 3362.98158 |
|  | 3 | 1 | 60.00% | 3362.981566 |
|  | 3 | 2 | 60.00% | 3362.981585 |
|  | 3 | 3 | 60.00% | 3362.981584 |
|  | 4 | 1 | 60.00% | 3362.981519 |
|  | 4 | 2 | 60.00% | 3362.981553 |
|  | 4 | 3 | 60.00% | 3362.978691 |
|  | 4 | 4 | 60.00% | 3362.981528 |
|  |  |  |  |  |
| 10000 | 1 | 1 | 60.00% | 6725.748869 |
|  | 2 | 1 | 60.00% | 6725.74884 |
|  | 2 | 2 | 60.00% | 6725.748873 |
|  | 3 | 1 | 60.00% | 6725.748578 |
|  | 3 | 2 | 60.00% | 6725.748873 |
|  | 3 | 3 | 60.00% | 6725.748873 |
|  | 4 | 1 | 60.00% | 6725.74389 |
|  | 4 | 2 | 60.00% | 6725.747346 |
|  | 4 | 3 | 97.00% | 4683.8583 |
|  | 4 | 4 | 92.00% | 6607.50094 |
|  |  |  |  |  |
| 20000 | 1 | 1 | 60.00% | 13451.28344 |
|  | 2 | 1 | 60.00% | 13451.28339 |
|  | 2 | 2 | 60.00% | 13451.28136 |
|  | 3 | 1 | 98.00% | 9445.95257 |
|  | 3 | 2 | 60.00% | 13451.28344 |
|  | 3 | 3 | 60.00% | 13451.28341 |
|  | 4 | 1 | 98.00% | 8175.261808 |
|  | 4 | 2 | 100.00% | nan |
|  | 4 | 3 | 100.00% | nan |
|  | 4 | 4 | 100.00% | nan |

**Observation**

From the above tables we can clearly see that combination of RELU, SIGMOID function is effective in case of Single Layer Neural Network with exactly 100.00% percent accuracy for almost all the considered observations, while the same combination of RELU, RELU, SIGMOID function in Double Layer Neural Network gives a poor result with low accuracy of nearly 60.00% as well as cost value in almost all the considered observations.

The combination of TANH, SIGMOID gives the best result with accuracy of exactly 100.00% in all considered observations even for lower number of iterations and number of nodes in hidden layers as well as with low overall cost value for the Neural Network as compared to other combinations.

The combination TANH, RELU, SIGMOID also gives a sufficiently good result in terms of low overall cost value, but gives low accuracy for lower number of iterations, and varied accuracy for few of the combinations of nodes in hidden layer for higher iterations.

We can also observe that all the combinations gives sufficiently good results in case of both accuracy and cost value when the number of iterations are at least 10,000 except in case of RELU, RELU, SIGMOID function combination which requires at least 4 nodes in the hidden layer for appropriate results.

**Conclusion**

We received almost 100.00% accuracy for most of the combinations (except RELU, RELU, SIGMOID) which states that the data was properly distributed over the classes, helping to clearly predict the classes with higher accuracy. We would prefer using Single Layer RELU, SIGMOID combination as it provides 100.00% accuracy for almost all observations with lower overall cost value as well.