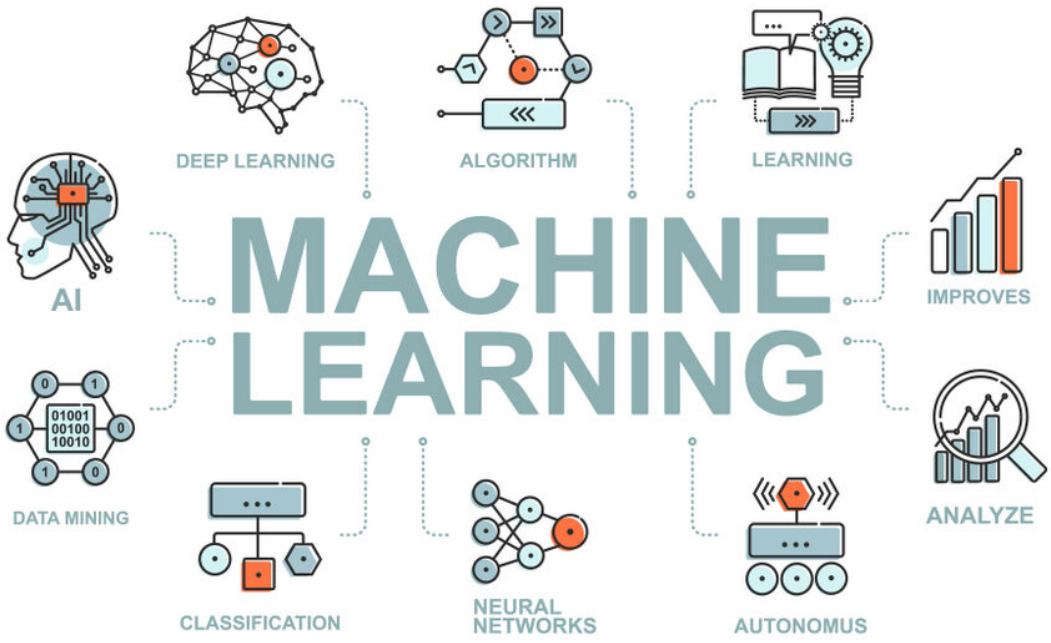
BITS F464

Assignment 2
MACHINE LEARNING



Team Members

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Introduction

In the second assignment, we were tasked with creating 2 models, one from scratch, where we had to implement Naive Bayes' and the second being Artificial Neural Network using Pytorch.

Part A

Data preprocessing

We first replace all the '?' with the most frequently occurring value in that feature, then we convert the categorical data to nominal data, for example, the salaries are converted from >50K and <=50K to 0 and 1.

Model 1: Naive Bayes

Naive Bayes is a probabilistic classification algorithm based on Bayes' theorem, which assumes that the features are conditionally independent given the class label. It calculates the probability of each class and the conditional probability of each feature given the class. Then it uses these probabilities to predict the class with the highest probability for a new data point. It is simple, fast, and works well with high-dimensional data.

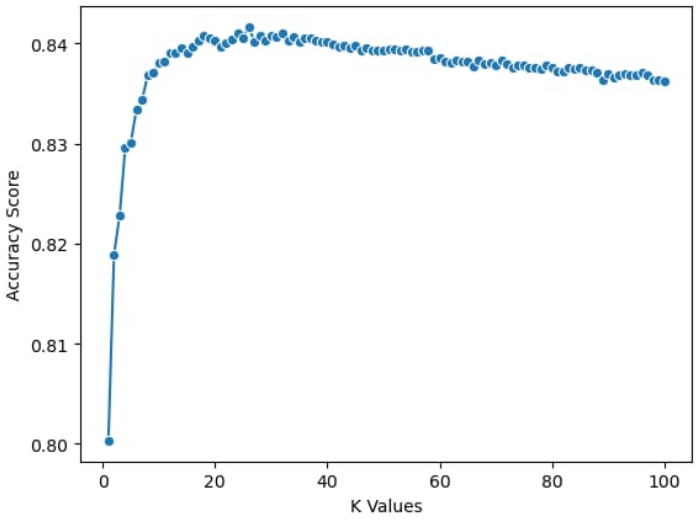
In Naive Baye's Classifier, we assume that the features are all independent. Therefore, we can multiply the probabilities of the various features.

We then calculate the likelihood of each value of each feature for both salary >50K and <= 50K. We then use these likelihood values to predict the salary of the testing examples. We've split the data into training(67%) and testing(33%).

Feature	**Statistic**
Accuracy	87.66%
Precision	70.76%
Recall	83.10%
F1	76.44%

Model 2: KNN

KNN is a non-parametric, lazy learning algorithm used for classification and regression tasks. Given a new data point, KNN finds the K training examples closest to it in the feature space, and predicts the class label based on the majority vote of the K neighbors. The choice of K affects the classifier's performance, with smaller values of K leading to more flexible models and larger values leading to smoother decision boundaries.



For KNN we did an analysis of the data to get the best 'K' value and took the model with the same.

Feature	**Statistic**
Accuracy	83.76%
Precision	71.57%
Recall	52.73%
F1	60.72%

Model 3: Logistic Regression

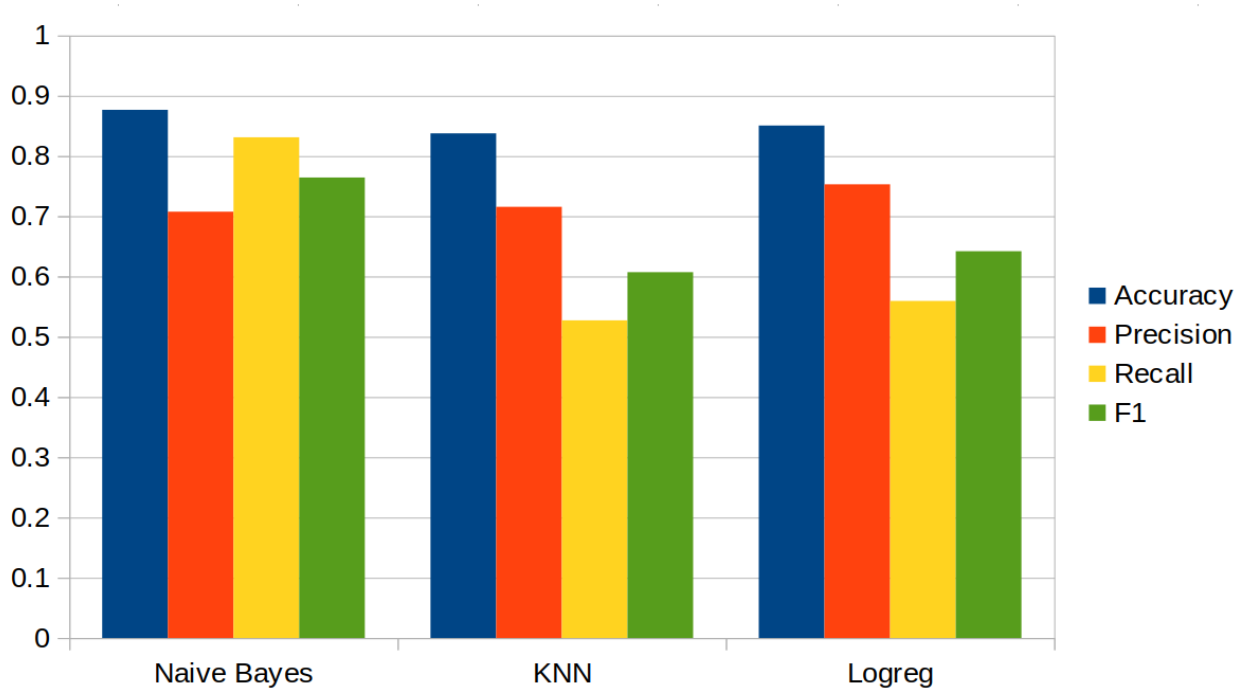
Logistic regression is a linear binary classification model can be generalized to multi-class classification using techniques like one-vs-rest or multinomial logistic regression. It models the probability of a data point belonging to a particular class using the logistic function, and fits the model parameters by minimizing the log-loss (cross-entropy) between the true

labels and the predicted probabilities. It is simple, interpretable, and works well for linearly separable data.

Due to the nature of logistic regeression, all categorical data were converted using one-hot encoding to achieve high accuracy and remove unnecessary bias.

Feature	**Statistic**
Accuracy	85.06%
Precision	75.31%
Recall	55.95%
F1	64.20%

Conclusion



As seen above Naive Bayes classifier is the better option compared to KNN and Logreg. This is because Logreg works well with continuous data that is normalized.

KNN also works better on continuous data. But Naive Bayes is defined for categorical data and works well in our case.

Part B: Artificial Neural Network: MNIST

We are considering **100 Epochs** and dataset splits of 67% for Training and 33% for Testing. We have 2 variants of **Hidden layers 2 and 3,** 2 variants of the **Number of neurons in each hidden layer, 100 and 150**, and 3 variants of **Activation functions TanH, Sigmoid, and RelU.**

In the ANN Classification Reports, We have macro and micro accuracies. Macro accuracy takes an average of all accuracies, while micro adds all numerators and adds all denominators and does the division. It also contains each class's precision, recall, and f1 score.

We used Pytorch to make these artificial neural networks and used the torch datasets repository only. In ANN, we convert the image, which is a 28x28, into a 784-sized tuple which we feed into the network, and using backpropagation on the training data, we settle the weights. Then we use this network with on the testing dataset and get probabilities of the number being each number, and we use the argmax function to find which of them has the highest probability and take that as output.

2 HIDDEN LAYERS, 100 NEURONS, TanH ACTIVATION FUNCTION:

```
Model #1
[[ 972    0    0    0    0    2    2    1    2    1]
 [   0 1128    1    1    0    0    1    1    3    0]
 [   4    1 1016    2    1    0    2    3    3    0]
 [   0    0    4  991    0    5    0    3    3    4]
 [   1    1    1    0  966    0    5    2    0    6]
 [   2    0    0   12    1  867    3    2    3    2]
 [   3    3    2    1    5    4  938    0    2    0]
 [   0    1   12    0    3    1    1 1005    1    4]
 [   2    0    4    2    3    2    2    3  951    5]
 [   0    2    0    3    9    4    0    6    2  983]]
Classification report for Hidden Layers: 2, Neurons in Each Hidden Lay
er: 100, Activation Function: t :
              precision    recall  f1-score   support

           0   0.987805  0.991837  0.989817       980
           1   0.992958  0.993833  0.993395      1135
           2   0.976923  0.984496  0.980695      1032
           3   0.979249  0.981188  0.980218      1010
           4   0.977733  0.983707  0.980711       982
           5   0.979661  0.971973  0.975802       892
           6   0.983229  0.979123  0.981172       958
           7   0.979532  0.977626  0.978578      1028
           8   0.980412  0.976386  0.978395       974
           9   0.978109  0.974232  0.976167      1009

    accuracy                       0.981700     10000
   macro avg   0.981561  0.981440  0.981495     10000
weighted avg   0.981700  0.981700  0.981694     10000
```

2 HIDDEN LAYERS, 100 NEURONS, Sigmoid ACTIVATION FUNCTION:

```
Model #2
[[ 973    0    1    1    0    0    2    1    2    0]
 [   0 1117    0    0    0    2    6    1    8    1]
 [   4    1 1002    2    4    0    4    4    9    2]
 [   0    0    3  969    1    9    0   10    4   14]
 [   1    0    2    0  967    0    4    1    0    7]
 [   1    0    0    6    2  875    4    1    2    1]
 [   3    1    2    0    4    3  945    0    0    0]
 [   2    2    9    0    4    0    0  996    4   11]
 [   3    0    1    3    5    9    4    3  938    8]
 [   1    2    0    0   20    6    1    1    1  977]]
Classification report for Hidden Layers: 2, Neurons in Each Hidden Lay
er: 100, Activation Function: s :
              precision    recall  f1-score   support

           0   0.984818  0.992857  0.988821       980
           1   0.994657  0.984141  0.989371      1135
           2   0.982353  0.970930  0.976608      1032
           3   0.987768  0.959406  0.973380      1010
           4   0.960278  0.984725  0.972348       982
           5   0.967920  0.980942  0.974388       892
           6   0.974227  0.986430  0.980290       958
           7   0.978389  0.968872  0.973607      1028
           8   0.969008  0.963039  0.966014       974
           9   0.956905  0.968285  0.962562      1009

    accuracy                       0.975900     10000
   macro avg   0.975632  0.975963  0.975739     10000
weighted avg   0.976029  0.975900  0.975906     10000
```

2 HIDDEN LAYERS, 100 NEURONS, RelU ACTIVATION FUNCTION:

```
Model #3
[[ 967    0    1    1    0    0    4    3    3    1]
 [   0 1126    1    2    0    0    1    1    4    0]
 [   2    1 1014    1    0    0    0    6    7    1]
 [   0    0    7  986    0    5    1    3    3    5]
 [   2    1    3    0  953    0    4    5    0   14]
 [   4    0    0    8    1  862    5    1   10    1]
 [   2    2    2    0    6    0  941    0    5    0]
 [   0    2    8    0    1    0    0 1001    3   13]
 [   1    0    2    3    4    1    1    2  956    4]
 [   0    4    0    1    9    1    1    5    3  985]]
Classification report for Hidden Layers: 2, Neurons in Each Hidden Lay
er: 100, Activation Function: r :
              precision    recall  f1-score   support

           0   0.988753  0.986735  0.987743       980
           1   0.991197  0.992070  0.991634      1135
           2   0.976879  0.982558  0.979710      1032
           3   0.984032  0.976238  0.980119      1010
           4   0.978439  0.970468  0.974438       982
           5   0.991945  0.966368  0.978989       892
           6   0.982255  0.982255  0.982255       958
           7   0.974684  0.973735  0.974209      1028
           8   0.961771  0.981520  0.971545       974
           9   0.961914  0.976214  0.969011      1009

    accuracy                       0.979100     10000
   macro avg   0.979187  0.978816  0.978965     10000
weighted avg   0.979195  0.979100  0.979113     10000
```

2 HIDDEN LAYERS, 150 NEURONS, TanH ACTIVATION FUNCTION:

```
Model #4
[[ 974    0    1    0    0    0    2    1    2    0]
 [   0 1127    1    1    0    0    2    1    3    0]
 [   1    2 1016    2    2    0    1    7    1    0]
 [   0    0    4  993    0    2    0    4    1    6]
 [   1    0    3    1  965    0    3    1    0    8]
 [   2    0    0    9    0  874    2    1    3    1]
 [   3    2    0    1    3    2  946    0    1    0]
 [   0    2   10    0    0    0    0 1009    3    4]
 [   4    0    1    4    3    2    0    3  954    3]
 [   1    2    0    1    7    2    1    2    3  990]]
Classification report for Hidden Layers: 2, Neurons in Each Hidden Lay
er: 150, Activation Function: t :
              precision    recall  f1-score   support

           0   0.987830  0.993878  0.990844       980
           1   0.992952  0.992952  0.992952      1135
           2   0.980695  0.984496  0.982592      1032
           3   0.981225  0.983168  0.982196      1010
           4   0.984694  0.982688  0.983690       982
           5   0.990930  0.979821  0.985344       892
           6   0.988506  0.987474  0.987990       958
           7   0.980564  0.981518  0.981040      1028
           8   0.982492  0.979466  0.980977       974
           9   0.978261  0.981169  0.979713      1009

    accuracy                       0.984800     10000
   macro avg   0.984815  0.984663  0.984734     10000
weighted avg   0.984809  0.984800  0.984800     10000
```

2 HIDDEN LAYERS, 150 NEURONS, Sigmoid ACTIVATION FUNCTION:

```
Model #5
[[ 970    0    1    2    1    0    1    0    2    3]
 [   0 1124    3    2    0    0    2    1    3    0]
 [   1    0 1017    5    1    0    1    3    3    1]
 [   1    0    1  994    0    3    0    3    7    1]
 [   1    1    2    0  966    0    4    2    1    5]
 [   2    0    0    8    2  870    3    1    4    2]
 [   3    1    1    0    4    5  943    0    1    0]
 [   1    2   11    0    1    0    0 1004    3    6]
 [   2    0    3    5    4    3    0    4  948    5]
 [   2    3    0    2    5    1    1    4    4  987]]
Classification report for Hidden Layers: 2, Neurons in Each Hidden Lay
er: 150, Activation Function: s :
              precision    recall  f1-score   support

           0   0.986775  0.989796  0.988283       980
           1   0.993811  0.990308  0.992056      1135
           2   0.978826  0.985465  0.982134      1032
           3   0.976424  0.984158  0.980276      1010
           4   0.981707  0.983707  0.982706       982
           5   0.986395  0.975336  0.980834       892
           6   0.987435  0.984342  0.985886       958
           7   0.982387  0.976654  0.979512      1028
           8   0.971311  0.973306  0.972308       974
           9   0.977228  0.978196  0.977712      1009

    accuracy                       0.982300     10000
   macro avg   0.982230  0.982127  0.982171     10000
weighted avg   0.982319  0.982300  0.982302     10000
```

2 HIDDEN LAYERS, 150 NEURONS, RelU ACTIVATION FUNCTION:

```
Model #6
[[ 975    1    1    0    0    0    1    1    1    0]
 [   0 1129    0    0    0    1    1    1    3    0]
 [   3    1 1013    3    1    0    0    4    7    0]
 [   0    0    2  996    1    1    0    4    5    1]
 [   1    0    4    0  964    0    2    2    1    8]
 [   2    0    0    6    1  870    5    1    5    2]
 [   2    2    2    1    3    4  944    0    0    0]
 [   1    2    8    1    1    0    0 1006    2    7]
 [   2    0    4    2    1    3    1    3  955    3]
 [   1    2    0    0    5    5    2    4    0  990]]
Classification report for Hidden Layers: 2, Neurons in Each Hidden Lay
er: 150, Activation Function: r :
              precision    recall  f1-score   support

           0   0.987842  0.994898  0.991357       980
           1   0.992964  0.994714  0.993838      1135
           2   0.979691  0.981589  0.980639      1032
           3   0.987116  0.986139  0.986627      1010
           4   0.986694  0.981670  0.984176       982
           5   0.984163  0.975336  0.979730       892
           6   0.987448  0.985386  0.986416       958
           7   0.980507  0.978599  0.979552      1028
           8   0.975485  0.980493  0.977983       974
           9   0.979228  0.981169  0.980198      1009

    accuracy                       0.984200     10000
   macro avg   0.984114  0.983999  0.984052     10000
weighted avg   0.984203  0.984200  0.984197     10000
```

3 HIDDEN LAYERS, 100 NEURONS, TanH ACTIVATION FUNCTION:

```
Model #7
[[ 973    0    2    0    0    0    2    1    2    0]
 [   0 1130    1    0    0    0    2    0    2    0]
 [   2    0 1014    5    4    0    0    3    4    0]
 [   1    0    3  986    0    5    0    9    4    2]
 [   1    0    2    0  961    0    5    4    3    6]
 [   2    0    0    8    1  871    4    1    5    0]
 [   2    3    2    1    2    3  945    0    0    0]
 [   0    2    9    0    0    0    0 1012    2    3]
 [   1    1    3    6    3    3    2    4  946    5]
 [   2    2    0    2   10    5    1    8    3  976]]
Classification report for Hidden Layers: 3, Neurons in Each Hidden Lay
er: 100, Activation Function: t :
              precision    recall  f1-score   support

           0   0.988821  0.992857  0.990835       980
           1   0.992970  0.995595  0.994281      1135
           2   0.978764  0.982558  0.980658      1032
           3   0.978175  0.976238  0.977205      1010
           4   0.979613  0.978615  0.979114       982
           5   0.981962  0.976457  0.979202       892
           6   0.983351  0.986430  0.984888       958
           7   0.971209  0.984436  0.977778      1028
           8   0.974253  0.971253  0.972751       974
           9   0.983871  0.967294  0.975512      1009

    accuracy                       0.981400     10000
   macro avg   0.981299  0.981173  0.981222     10000
weighted avg   0.981410  0.981400  0.981391     10000
```

3 HIDDEN LAYERS, 100 NEURONS, Sigmoid ACTIVATION FUNCTION:

```
Model #8
[[ 966    0    2    2    2    2    3    1    1    1]
 [   0 1126    0    2    0    1    1    1    4    0]
 [   3    4 1010    6    2    0    2    3    2    0]
 [   0    0    3  989    0    3    0    5    4    6]
 [   3    0    1    0  963    0    4    2    1    8]
 [   2    1    0    6    2  870    5    0    3    3]
 [   2    3    2    1    7    4  935    0    4    0]
 [   2    4   10    3    1    0    0 1000    2    6]
 [   2    0    4    5    2    2    2    3  950    4]
 [   3    2    0    3    9    3    0    0    3  986]]
Classification report for Hidden Layers: 3, Neurons in Each Hidden Lay
er: 100, Activation Function: s :
              precision    recall  f1-score   support

           0   0.982706  0.985714  0.984208       980
           1   0.987719  0.992070  0.989890      1135
           2   0.978682  0.978682  0.978682      1032
           3   0.972468  0.979208  0.975826      1010
           4   0.974696  0.980652  0.977665       982
           5   0.983051  0.975336  0.979178       892
           6   0.982143  0.975992  0.979058       958
           7   0.985222  0.972763  0.978953      1028
           8   0.975359  0.975359  0.975359       974
           9   0.972387  0.977205  0.974790      1009

    accuracy                       0.979500     10000
   macro avg   0.979443  0.979298  0.979361     10000
weighted avg   0.979518  0.979500  0.979499     10000
```

3 HIDDEN LAYERS, 100 NEURONS, RelU ACTIVATION FUNCTION:

```
Model #9
[[ 970    0    2    1    0    0    1    3    1    2]
 [   0 1130    0    1    0    1    0    1    2    0]
 [   4    0 1013    2    2    0    1    7    3    0]
 [   0    0    4  993    0    2    0    3    4    4]
 [   0    0    2    0  964    1    5    2    1    7]
 [   3    0    0   11    0  863    5    1    3    6]
 [   3    2    1    1    5    6  932    0    8    0]
 [   0    1    8    0    0    0    0 1008    4    7]
 [   1    0    4    6    2    3    3    3  947    5]
 [   2    2    0    1   11    5    0    1    4  983]]
Classification report for Hidden Layers: 3, Neurons in Each Hidden Lay
er: 100, Activation Function: r :
              precision    recall  f1-score   support

           0   0.986775  0.989796  0.988283       980
           1   0.995595  0.995595  0.995595      1135
           2   0.979691  0.981589  0.980639      1032
           3   0.977362  0.983168  0.980257      1010
           4   0.979675  0.981670  0.980671       982
           5   0.979569  0.967489  0.973491       892
           6   0.984161  0.972860  0.978478       958
           7   0.979592  0.980545  0.980068      1028
           8   0.969294  0.972279  0.970784       974
           9   0.969428  0.974232  0.971824      1009

    accuracy                       0.980300     10000
   macro avg   0.980114  0.979922  0.980009     10000
weighted avg   0.980312  0.980300  0.980298     10000
```

3 HIDDEN LAYERS, 150 NEURONS, TanH ACTIVATION FUNCTION:

```
Model #10
[[ 972    1    0    1    0    1    4    1    0    0]
 [   0 1128    1    2    0    0    3    1    0    0]
 [   0    0 1017    1    1    0    2    5    5    1]
 [   0    0    4  993    0    2    0    2    2    7]
 [   1    0    1    0  961    0    4    2    1   12]
 [   2    0    0    7    1  872    2    2    4    2]
 [   1    2    1    1    4    3  944    0    2    0]
 [   1    3    7    1    0    0    0 1009    1    6]
 [   3    0    4    5    1    2    1    2  950    6]
 [   3    2    0    2    5    2    1    3    0  991]]
Classification report for Hidden Layers: 3, Neurons in Each Hidden Lay
er: 150, Activation Function: t :
              precision    recall  f1-score   support

           0   0.988810  0.991837  0.990321       980
           1   0.992958  0.993833  0.993395      1135
           2   0.982609  0.985465  0.984035      1032
           3   0.980257  0.983168  0.981710      1010
           4   0.987667  0.978615  0.983120       982
           5   0.988662  0.977578  0.983089       892
           6   0.982310  0.985386  0.983846       958
           7   0.982473  0.981518  0.981995      1028
           8   0.984456  0.975359  0.979887       974
           9   0.966829  0.982161  0.974435      1009

    accuracy                       0.983700     10000
   macro avg   0.983703  0.983492  0.983583     10000
weighted avg   0.983735  0.983700  0.983704     10000
```

3 HIDDEN LAYERS, 150 NEURONS, Sigmoid ACTIVATION FUNCTION:

```
Model #11
[[ 972    0    2    0    0    1    3    0    1    1]
 [   0 1124    3    3    0    0    1    1    3    0]
 [   0    2 1014    5    2    0    2    3    4    0]
 [   0    0    6  985    0    6    0    4    5    4]
 [   0    1    4    0  952    1    7    3    1   13]
 [   3    0    0    8    0  872    2    0    5    2]
 [   3    2    1    0    3    4  943    0    2    0]
 [   1    4    6    2    1    0    0 1006    0    8]
 [   2    0    5    6    1    4    0    4  948    4]
 [   2    2    0    3    8    3    0    2    2  987]]
Classification report for Hidden Layers: 3, Neurons in Each Hidden Lay
er: 150, Activation Function: s :
              precision    recall  f1-score   support

           0   0.988810  0.991837  0.990321       980
           1   0.990308  0.990308  0.990308      1135
           2   0.974063  0.982558  0.978292      1032
           3   0.973320  0.975248  0.974283      1010
           4   0.984488  0.969450  0.976911       982
           5   0.978676  0.977578  0.978127       892
           6   0.984342  0.984342  0.984342       958
           7   0.983382  0.978599  0.980985      1028
           8   0.976313  0.973306  0.974807       974
           9   0.968597  0.978196  0.973373      1009

    accuracy                       0.980300     10000
   macro avg   0.980230  0.980142  0.980175     10000
weighted avg   0.980323  0.980300  0.980300     10000
```

3 HIDDEN LAYERS, 150 NEURONS, RelU ACTIVATION FUNCTION:

```
Model #12
[[ 974    0    0    1    0    0    1    1    3    0]
 [   0 1125    2    0    0    1    1    0    6    0]
 [   3    4 1011    2    1    0    0    1   10    0]
 [   2    0    2  990    0    4    0    5    6    1]
 [   1    2    3    0  963    0    3    2    0    8]
 [   2    1    0    8    1  868    4    1    5    2]
 [   4    1    0    1    6    3  943    0    0    0]
 [   1    9    7    0    0    0    0 1002    3    6]
 [   0    0    2    4    1    2    1    1  960    3]
 [   2    5    0    0    7    7    0    2    4  982]]
Classification report for Hidden Layers: 3, Neurons in Each Hidden Lay
er: 150, Activation Function: r :
              precision    recall  f1-score   support

           0   0.984833  0.993878  0.989335       980
           1   0.980820  0.991189  0.985977      1135
           2   0.984421  0.979651  0.982030      1032
           3   0.984095  0.980198  0.982143      1010
           4   0.983657  0.980652  0.982152       982
           5   0.980791  0.973094  0.976927       892
           6   0.989507  0.984342  0.986918       958
           7   0.987192  0.974708  0.980910      1028
           8   0.962889  0.985626  0.974125       974
           9   0.980040  0.973241  0.976629      1009

    accuracy                       0.981800     10000
   macro avg   0.981824  0.981658  0.981715     10000
weighted avg   0.981854  0.981800  0.981800     10000
```

3 HIDDEN LAYERS, 100 + 150 NEURONS, TanH ACTIVATION FUNCTION:

```
[[ 952    0    1    2    2    2   15    2    4    0]
 [   0 1111    4    2    0    2    2    6    8    0]
 [   3    0  989   10    6    1    6    8    8    1]
 [   0    0    7  969    0    4    0   10   13    7]
 [   1    1    3    0  942    0    6    3    1   25]
 [   6    0    0   19    2  833    4    4   19    5]
 [   3    3    0    1    8   16  916    0   11    0]
 [   0    3   13    6    2    1    0  989    0   14]
 [   2    0    5   12    3    5    2    6  937    2]
 [   4    2    0    7   17    4    1   10   10  954]]
Classification report for Hidden Layers: 2, Neurons in Each Hidden Lay
er: 150, Activation Function: t :
              precision    recall  f1-score   support

           0   0.980433  0.971429  0.975910       980
           1   0.991964  0.978855  0.985366      1135
           2   0.967710  0.958333  0.962999      1032
           3   0.942607  0.959406  0.950932      1010
           4   0.959267  0.959267  0.959267       982
           5   0.959677  0.933857  0.946591       892
           6   0.962185  0.956159  0.959162       958
           7   0.952794  0.962062  0.957406      1028
           8   0.926805  0.962012  0.944081       974
           9   0.946429  0.945491  0.945959      1009

    accuracy                       0.959200     10000
   macro avg   0.958987  0.958687  0.958767     10000
weighted avg   0.959435  0.959200  0.959250     10000
```

3 HIDDEN LAYERS, 100 + 150 NEURONS, Sigmoid ACTIVATION FUNCTION:

```
[[ 973    0    0    0    0    1    1    1    4    0]
 [   0 1130    0    1    0    0    1    1    2    0]
 [   1    2 1014    2    1    0    1    2    8    1]
 [   0    0    3  997    0    3    0    3    2    2]
 [   2    0    3    0  958    0    4    2    1   12]
 [   2    0    0    7    1  872    2    2    4    2]
 [   2    2    0    1    4    4  944    0    1    0]
 [   0    1    9    0    0    1    0 1009    2    6]
 [   3    0    3    6    2    1    0    3  951    5]
 [   3    2    0    3    9    2    0    1    4  985]]
Classification report for Hidden Layers: 2, Neurons in Each Hidden Lay
er: 150, Activation Function: t :
              precision    recall  f1-score   support

           0   0.986815  0.992857  0.989827       980
           1   0.993843  0.995595  0.994718      1135
           2   0.982558  0.982558  0.982558      1032
           3   0.980334  0.987129  0.983720      1010
           4   0.982564  0.975560  0.979050       982
           5   0.986425  0.977578  0.981982       892
           6   0.990556  0.985386  0.987964       958
           7   0.985352  0.981518  0.983431      1028
           8   0.971399  0.976386  0.973886       974
           9   0.972359  0.976214  0.974283      1009

    accuracy                       0.983300     10000
   macro avg   0.983221  0.983078  0.983142     10000
weighted avg   0.983315  0.983300  0.983300     10000
```

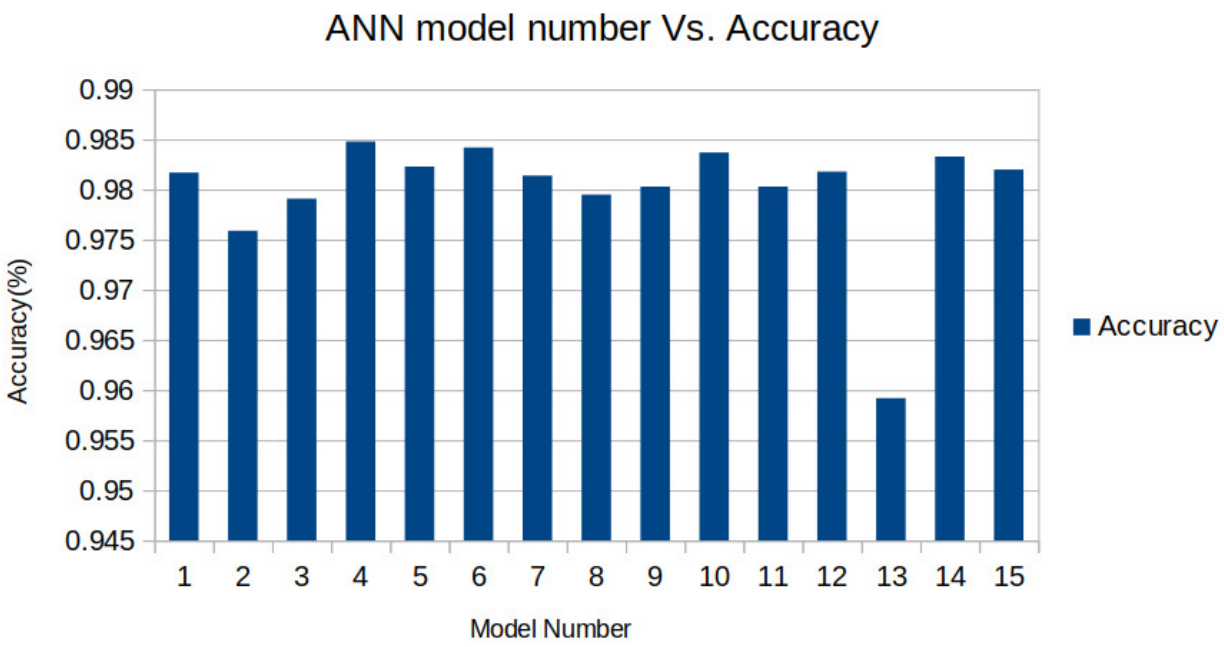
3 HIDDEN LAYERS, 100 + 150 NEURONS, RelU ACTIVATION FUNCTION:

```
[[ 972    0    3    0    0    0    4    1    0    0]
 [   1 1124    1    0    0    1    3    0    5    0]
 [   2    0 1014    2    1    0    3    4    6    0]
 [   0    0    4  986    0   10    0    2    6    2]
 [   4    0    3    0  949    1    5    1    1   18]
 [   2    0    0    5    1  874    3    2    4    1]
 [   2    2    0    1    1    5  944    0    2    1]
 [   1    2    6    1    1    0    0 1007    2    8]
 [   0    0    4    4    1    0    1    2  957    5]
 [   1    3    0    0    3    4    1    3    1  993]]
Classification report for Hidden Layers: 2, Neurons in Each Hidden Lay
er: 150, Activation Function: t :
              precision    recall  f1-score   support

           0   0.986802  0.991837  0.989313       980
           1   0.993811  0.990308  0.992056      1135
           2   0.979710  0.982558  0.981132      1032
           3   0.986987  0.976238  0.981583      1010
           4   0.991641  0.966395  0.978855       982
           5   0.976536  0.979821  0.978176       892
           6   0.979253  0.985386  0.982310       958
           7   0.985323  0.979572  0.982439      1028
           8   0.972561  0.982546  0.977528       974
           9   0.965953  0.984143  0.974963      1009

    accuracy                       0.982000     10000
   macro avg   0.981858  0.981880  0.981836     10000
weighted avg   0.982078  0.982000  0.982006     10000
```

Comparison of all ANN Models



CONCLUSION

- We observe that over 100 epochs, neural networks perform way better than other Machine Learning algorithms.
- The accuracy is similar between models, which would mean that these models have similar accuracies, and there is no statistically significant model compared to the other models.
- We also observe that TanH tends to have higher accuracy than Sigmoid and RelU in most cases. We are not concluding anything here but are just noting our observations.
- We also observe a slight increase in accuracy with an increase in neurons; this is because there is more capability for the model to learn from the data due to multiple data points.