SMAI Assignment 4
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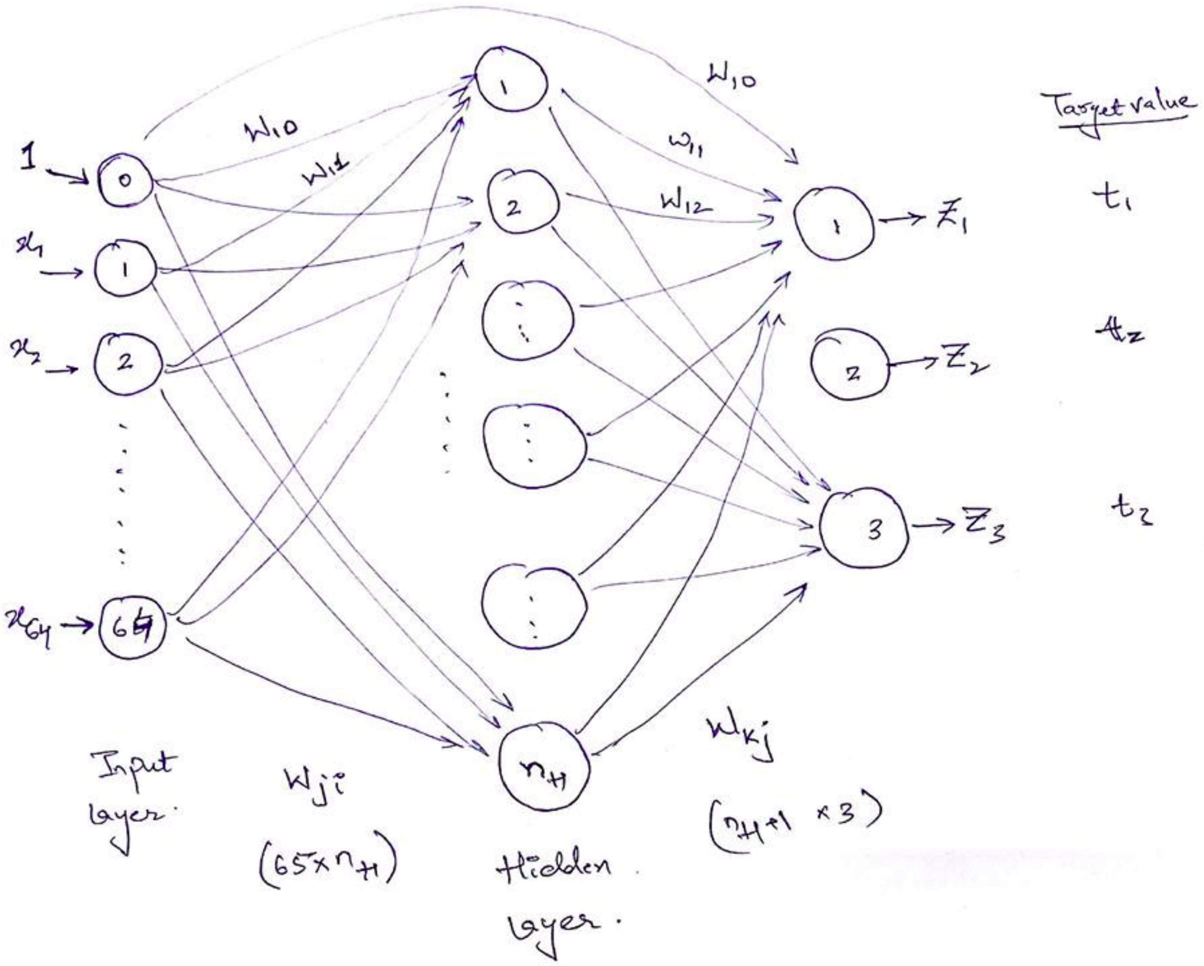
20162080(Mtech. CSE)

1.Neural Networks - Training 3-layer Neural Network
Algorithm:

Neural network architecture -



Final Weight Vectors (Final Wji and Wkj for Hidden Units and the Accuracy -)

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('----Number of Hidden Layers-----', 3,5,10,15)
('Iteration=', 37106, '\nFinal Wji---', array([[-0.26570635,  0.07391975,
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       [-0.39331659,  0.05023629, -0.07303955],
       [-0.79401293,  0.3698436 , -0.47886831],
       [ 0.35625745,  0.04402892, -0.49939111],
       [-0.05084843, -0.03693933, -0.19477125],
       [ 0.0690066 ,  0.01805038, -0.21783437],
       [-0.03138705, -0.00987999,  0.0726756 ],
       [-0.58168617,  0.72915436, -0.29607846],
       [-0.86248732,  0.73313985, -0.11269327],
       [ 0.0209049 ,  0.15987557,  0.03083071],
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       [ 0.15827046,  0.16561665, -0.16365404],
       [ 0.23278955, -0.35593301,  0.03437384],
       [ 0.96185896, -0.76268694, -0.74310952],
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       [-0.02890077, -0.2642759 ,  0.52757582],
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       [ 0.14069409, -0.14353401,  0.23010524],
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       [ 0.3580505 , -0.34348066,  0.78686978],
       [ 0.52658567, -0.46273581, -0.89365892],
       [ 0.35806789, -0.28309653, -0.89428713],
       [ 0.09370931, -0.05925503,  0.03497275],
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       [-0.6472375 ,  0.65393355, -0.40323853],
       [ 0.20862124,  0.1099044 , -0.00337727],
       [ 0.4027107 , -0.71161357, -0.10625711],
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       [-0.74392714,  0.44220458, -0.64860559],
       [-0.12362819, -0.52786166, -0.20700581],
       [ 0.03745295,  0.10510765, -0.03616453]]))
('Iteration=', 37106, '\nFinal Wkj---', array([[-0.70037519,  2.91685673,
-3.16836086],
       [-1.7465357 , -3.43490568,  3.87642066],
       [ 6.07105248, -5.83695669, -1.35037994],
       [-2.33069894, -0.09624562, -0.40771361]]))
('Accuracy: ', 0.9869646182495344)
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       [ -1.55931766e-01,   1.68528887e-01,   1.71225412e-01,
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       [ -2.38066735e-01,  -5.31190596e-02,  -1.77556410e-01,
          3.11423254e-01,  -9.62218767e-02],
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('\nAccuracy: ', 0.9925512104283054)
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```

```
         -1.91512568e-01,  -5.86480983e-02,  -1.83593025e-01,
         -1.68334123e-01,   4.00122944e-01,   4.87169077e-02,
         -1.87080546e-01,   3.61726816e-01,  -6.43466412e-02,
         -2.88138061e-02,   2.54123328e-02,  -9.70987920e-02],
       [ -4.74778744e-03,   1.92056150e-01,   3.19695542e-02,
         -2.70801951e-01,   2.94846602e-01,  -5.83283371e-02,
          2.06483497e-02,   1.81480304e-01,   2.19297788e-01,
         -6.92248857e-02,  -9.38226211e-02,   9.98623792e-03,
          2.72286350e-02,  -7.81084868e-02,  -3.68122598e-03],
       [  1.48978645e-01,   3.19340893e-02,   9.18820577e-02,
          1.90003610e-01,   1.04613076e-01,  -9.14286280e-03,
          6.92752516e-02,   3.39509556e-01,   1.69913513e-02,
          5.45924407e-02,  -1.80747503e-02,  -1.11893960e-02,
          1.11625798e-02,  -6.14958694e-02,   8.50419333e-04],
       [ -2.27625833e-01,   4.01475772e-02,   2.73820844e-02,
         -1.05899502e-01,   8.17565153e-02,  -1.54559939e-01,
          1.31373386e-02,  -2.44432459e-02,   2.38160999e-01,
         -9.57953816e-02,   3.02002948e-01,   9.77511191e-02,
         -2.45379875e-01,   9.39264960e-02,  -5.33753109e-02],
       [ -3.65954160e-01,   8.93659665e-02,   9.05342745e-02,
         -8.99466938e-02,   1.74299710e-01,  -3.88705091e-01,
         -5.46197116e-02,   1.85782858e-02,   1.10320899e-01,
         -7.06187099e-03,   1.43736894e-01,  -1.01848614e-01,
         -2.50304884e-01,   1.92151530e-01,  -1.27424747e-01],
       [  1.03536607e-01,  -2.18912181e-02,  -7.59745295e-02,
         -1.53926546e-01,   1.88190665e-01,  -8.20396711e-02,
         -5.94352214e-02,   2.69316217e-02,  -1.67214110e-01,
          1.55607735e-01,  -4.46807928e-02,   2.83890841e-01,
         -3.09749564e-02,  -1.30001048e-01,   1.00036174e-01],
       [  4.75679177e-02,   2.82781586e-02,   2.06366158e-01,
          1.56921631e-01,   4.80500935e-02,   8.84680495e-02,
         -2.01489544e-01,  -2.45748903e-01,  -1.18087495e-01,
          2.56988547e-01,  -6.17453770e-02,  -1.68670099e-01,
         -1.25349484e-02,  -5.46262271e-02,  -7.27392503e-02]]))
('Iteration=', 10187, '\nFinal Wkj---', array([[ 0.25047723,  0.73235364,
-1.78245448],
       [ 0.31831658, -1.75068263,  1.1872148 ],
       [ 0.15155643, -1.51338167,  1.36681937],
       [ 1.20183752, -0.11745942, -1.09951318],
       [-0.71688272,  0.09141377, -0.10797929],
       [ 1.24127661, -0.27322423, -0.44883554],
       [ 1.19000199, -0.54807808, -0.64527404],
       [-0.71879957,  0.06587331, -0.39609993],
       [-0.21062977, -0.14933753, -0.04734486],
       [-0.22918773, -0.36095731,  0.11013174],
       [-1.55344798,  0.71591549,  0.424725  ],
       [-0.17212845, -0.42101879, -0.28629303],
       [ 1.19383895, -0.68202852, -1.01597348],
       [-0.33681399, -1.15387536,  1.50529869],
       [-0.40967077,  1.54891202, -0.77064032],
       [-0.47601387,  0.25837828, -0.69625409]]))
('Accuracy: ', 0.9925512104283054)
```

2. Support Vector Machine - Train a SVM Classifier

Python Implementation:

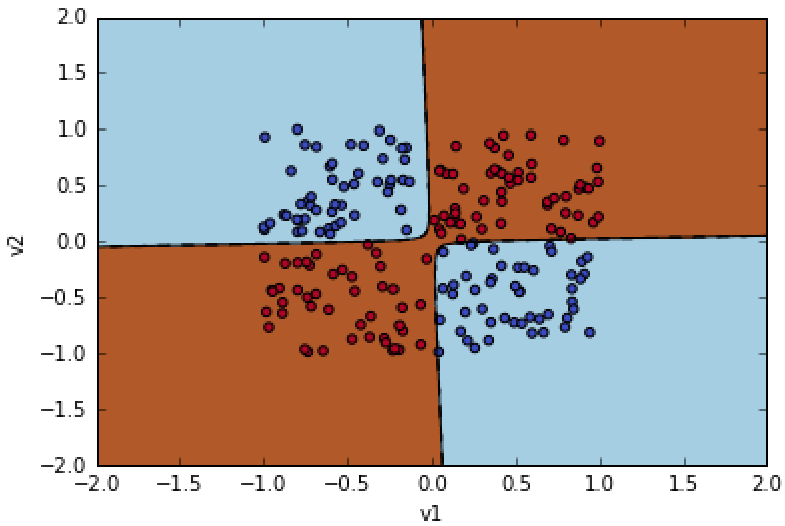
```
def checkAccuracy(kernelType):
    C = [1, 10, 100,10000]
    D = [2, 3, 4]
    for c in C:
        for d in D:
            accuracy = numpy.array([],dtype=float)
            clf = svm.SVC(kernel=kernelType, degree=d, C=c)
            for i in range(30):
                kf = KFold(n_splits=10,shuffle=True)
                tmpAccuracy = 0.0
                for train_index, test_index in kf.split(X):
                    X_train, X_test = X[train_index], X[test_index]
                    Label_train, Label_test = Label[train_index], Label[test_index]
                    clf.fit(X_train, Label_train)
                    outputTest = clf.predict(X_test)
                    outputDiff = numpy.subtract(outputTest, Label_test)
                    tmpAccuracy += len(outputDiff) - numpy.count_nonzero(outputDiff)
                tmpAccuracy /= len(Label)
                accuracy = numpy.append(accuracy, tmpAccuracy)
            standardDev = numpy.std(accuracy)
            accuracy = numpy.mean(accuracy)
            print(c, d, accuracy, standardDev)

def plot(kernelType,c,d):
    if kernelType == "poly":
        clf = svm.SVC(kernel=kernelType, degree=d, C=c)
    elif kernelType == "rbf":
        clf = svm.SVC(kernel=kernelType, gamma=d, C=c)
    clf.fit(X, Label)
    h = .002
    # create a mesh to plot in
    x_min = -2
    x_max = 2
    y_min = -2
    y_max = 2
    xx, yy = numpy.meshgrid(numpy.arange(x_min, x_max, h),
                         numpy.arange(y_min, y_max, h))
    Z = clf.predict(numpy.c_[xx.ravel(), yy.ravel()])
    # Put the result into a color plot
    Z = Z.reshape(xx.shape)
    #plt.contourf(xx, yy, Z, cmap=plt.cm.coolwarm, alpha=0.8)
    plt.pcolormesh(xx, yy, Z > 0, cmap=plt.cm.Paired)
    plt.contour(xx, yy, Z, colors=['k', 'k', 'k'], linestyles=['--', '-', '--'],levels=[-.5, 0, .5])
    # Plot also the training points
    plt.scatter(X[:, 0], X[:, 1], c=Label, marker='o', cmap=plt.cm.coolwarm)
    plt.xlabel('v1')
    plt.ylabel('v2')
    plt.xlim(xx.min(), xx.max())
    plt.ylim(yy.min(), yy.max())
    plt.show()
```

Output -

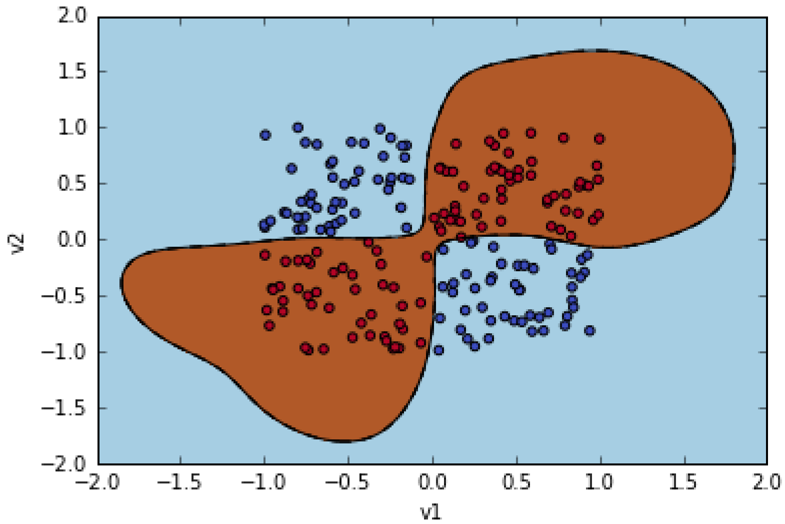
Polynomial Kernel

```
(1, 2, 0.9641666666666662, 0.011908213785264169)
(1, 3, 0.42083333333333339, 0.02359672764506883)
(1, 4, 0.79533333333333334, 0.032632635334721105)
(10, 2, 0.96483333333333332, 0.0020344259359556189)
(10, 3, 0.44949999999999996, 0.024978323936298577)
(10, 4, 0.90033333333333343, 0.018299969641747755)
(100, 2, 0.97483333333333355, 0.00089752746785575139)
(100, 3, 0.47383333333333327, 0.025745010304048344)
(100, 4, 0.93566666666666665, 0.011160446028522102)
(10000, 2, 0.98549999999999982, 0.0019790570145063213)
(10000, 3, 0.47066666666666668, 0.022425184255405545)
(10000, 4, 0.95733333333333337, 0.0028087165910587889)
Plotting graph for C=10000, d=2
```




```
('RBF Kernel', 100, 4)
(1, 2, 0.95916666666666661, 0.0086682690826305683)
(1, 3, 0.95633333333333326, 0.011323525167642014)
(1, 4, 0.96083333333333332, 0.0086682690826305597)
(10, 2, 0.96950000000000003, 0.0053774219349672307)
(10, 3, 0.96766666666666645, 0.0046067583203617561)
(10, 4, 0.96883333333333332, 0.0038042374035044458)
(100, 2, 0.97949999999999993, 0.0047169905660283057)
(100, 3, 0.97766666666666668, 0.0038151743807532026)
(100, 4, 0.97883333333333356, 0.0044127340982912456)
(10000, 2, 0.97799999999999998, 0.0054160256030906448)
(10000, 3, 0.97850000000000015, 0.0064743081998516827)
(10000, 4, 0.97966666666666657, 0.0057638721552635335)

Plotting graph for C=10000, gamma=4
```



Comparisons with various kernels

- RBF kernel takes less training time than other kernels. It is capable of separating
the data non-linearly.
- RBF kernel gives best performance for training time in classification by SVM.

● RBF kernels perform better than the linear and polynomial kernel. However, it is
difficult to find an optimum parameters σ and equivalent C that gives better result
for a given problem.
● Polynomial Kernel gives good classification accuracy with minimum number of support vectors and low classification error.
● RBF gives similar result as polynomial with minimum training error but for some
cases the number of support vector and classification error increases.

3. Implement a Naive Bayes Classifier for UCI Census-Income (KDD) Data Set using only the Discrete and Categorical attributes/features

<u>Python Implementation:</u>

```
import pandas as pd
import numpy as np
import math
from sklearn.model_selection import KFold
from sklearn.metrics import accuracy_score

data = pd.read_csv("census-income.data")
categorical_attributes = ['ACLSWKR','ADTIND','ADTOCC','AHGA','AHSCOL','AMARITL','AMJIND','AMJOCC','ARACE',
                          'AREORGN','ASEX','AUNMEM','AUNTYPE','AWKSTAT','FILESTAT','GRINREG','GRINST','HHDFMX',
                          'HHDREL','MIGMTR1','MIGMTR3','MIGMTR4','MIGSAME','MIGSUN','PARENT','PEFNTVTY',
                          'PEMNTVTY','PENATVTY','PRCITSHP','SEOTR','VETQVA','VETYN','YEAR']
#continuous_attributes = ['AAGE','AHRSPAY','CAPGAIN','CAPLOSS','NOEMP','WKSWORK']
cl=['INCOME']
#Handling missing values
data = data.loc[:,categorical_attributes+cl]
mode = data.loc[data.GRINST != " ?", "GRINST"].mode().iloc[0]
data.loc[data.GRINST == " ?", "GRINST"] = mode

mode = data.loc[data.MIGMTR3 != " ?", "MIGMTR3"].mode().iloc[0]
data.loc[data.MIGMTR3 == " ?", "MIGMTR3"] = mode

mode = data.loc[data.MIGMTR4 != " ?", "MIGMTR4"].mode().iloc[0]
data.loc[data.MIGMTR4 == " ?", "MIGMTR4"] = mode

mode = data.loc[data.MIGSAME != " ?", "MIGSAME"].mode().iloc[0]
data.loc[data.MIGSAME == " ?", "MIGSAME"] = mode

mode = data.loc[data.PEFNTVTY != " ?", "PEFNTVTY"].mode().iloc[0]
data.loc[data.PEFNTVTY == " ?", "PEFNTVTY"] = mode

mode = data.loc[data.PEMNTVTY != " ?", "PEMNTVTY"].mode().iloc[0]
data.loc[data.PEMNTVTY == " ?", "PEMNTVTY"] = mode

mode = data.loc[data.PENATVTY != " ?", "PENATVTY"].mode().iloc[0]
data.loc[data.PENATVTY == " ?", "PENATVTY"] = mode

data["MIGMTR1"] = str(data["MIGMTR1"])

#Binning some of the Continuous Attributes
data_categorical["WAGE_BIN"] = pd.cut(data.AHRSPAY, bins=1000, labels=False)
categorical_attributes.insert(0, "WAGE_BIN")

data_categorical["CAPGAIN_BIN"] = pd.cut(data.CAPGAIN, bins=132, labels=False)
categorical_attributes.insert(0, "CAPGAIN_BIN")

data_categorical["CAPLOSS_BIN"] = pd.cut(data.CAPLOSS, bins=113, labels=False)
categorical_attributes.insert(0, "CAPLOSS_BIN")

Accuracy = np.array([],dtype=float)
for i in range(30):
      kf = KFold(n_splits=10,shuffle=True)
      data = np.array(data)
      accuracy = 0.0
      for train_index, test_index in kf.split(data):
            allAttributes=categorical_attributes+cl
            trainData = pd.DataFrame(data[train_index], columns=allAttributes)
```

```
        testData = pd.DataFrame(data[test_index], columns=allAttributes)
        classLessIncome = trainData.loc[trainData.INCOME == " - 50000.", :]
        classMoreIncome = trainData.loc[trainData.INCOME == " 50000+.", :]
        classLessMean = {}
        classMoreMean = {}
        classLessStd = {}
        classMoreStd = {}
        numLess = classLessIncome.shape[0]
        numMore = classMoreIncome.shape[0]
        probLess = math.log(numLess/trainData.shape[0])  #a-priori probability (log probabilities)
        probMore = math.log(numMore/trainData.shape[0])
        classLessDict = {}
        classMoreDict = {}
        for attribute in categorical_attributes:
            classLessDict[attribute] = dict(classLessIncome[attribute].value_counts()/numLess)
            classMoreDict[attribute] = dict(classMoreIncome[attribute].value_counts()/numMore)
        #testing phase
        tmpAcc = 0.0
        for i in range(testData.shape[0]):
            X = testData.iloc[i:i+1]
            posteriorLess = probLess
            posteriorMore = probMore
            for attribute in categorical_attributes[:-1]:
                if X[attribute].iloc[0] in classLessDict[attribute].keys():
                    posteriorLess += math.log(classLessDict[attribute][X[attribute].iloc[0]])
                if X[attribute].iloc[0] in classMoreDict[attribute].keys():
                    posteriorMore += math.log(classMoreDict[attribute][X[attribute].iloc[0]])
            if posteriorLess > posteriorMore and X['INCOME'].iloc[0] == " - 50000.":
                tmpAcc += 1
            elif posteriorMore > posteriorLess and X['INCOME'].iloc[0] == " 50000+.":
                tmpAcc += 1
        tmpAcc /= testData.shape[0]
        accuracy += tmpAcc
    accuracy /= 10
    print(accuracy)
    Accuracy = np.append(Accuracy, accuracy)
print("Mean: ", np.mean(Accuracy))
print("Std-Dev: ", np.std(Accuracy))
```

<u>Output (Accuracy on scale 0-1 for two epochs):</u>

<u>Data Summary – (Mean and Standard Deviation of Continuous Attributes)</u>

```
AAGE 34.4941986638 22.310839296
AHRSPAY 55.426908176 274.895765018
CAPGAIN 434.718989791 4697.51950779
CAPLOSS 37.3137883853 271.895746998
WKSWORK 23.1748971297 24.4114269928
```

```
kanishtha@kanishtha-Vostro-3558:~/Desktop/Assignment3$ python3 naiveBayes.py
0.7716253152808057
0.7714950427208832
```

`Standard deviation of accuracies:  0.00923246987539`

<u>Procedure:</u>

10-fold cross validation has been applied 30 times and

<u>Dealing with Real attributes:</u>

Added relevant continuous attributes(WAGE,CAPGAIN,CAPLOSS) with binning. No of bins decided based on distinct values present for that Attribute.

```
data["WAGE_BIN"] = pd.cut(data.AHRSPAY, bins=1000, labels=False)
categorical_attributes.insert(0, "WAGE_BIN")

data["CAPGAIN_BIN"] = pd.cut(data.CAPGAIN, bins=132, labels=False)
categorical_attributes.insert(0, "CAPGAIN_BIN")

data["CAPLOSS_BIN"] = pd.cut(data.CAPLOSS, bins=113, labels=False)
categorical_attributes.insert(0, "CAPLOSS_BIN")
```

Handling missing entries:

Missing values are only present in categorical attributes and each such attribute with missing values has one particular value which is very dominatingly occurring for that attribute. So the missing value has been repaced by the mode for that attribute.