**Output for fuzzy three-layered MLP (no initial knowledge encoding):**

Observation I

Neurons in hidden layer = 12

Neurons in input layer = 9

Neurons in output layer = 6

No of epochs = 50 (starting)

learning rate = 0.1

Training set = 60%

[[13 0 0 0 14 2]

[12 0 0 0 2 22]

[ 0 0 69 0 0 0]

[ 0 0 0 21 0 40]

[ 0 0 40 0 30 13]

[ 0 0 0 0 0 72]]

False Positives

[12 0 40 0 16 77]

False Negetives

[16 36 0 40 53 0]

True Positives

[13 0 69 21 30 72]

True Negetives

[309 314 241 289 251 201]

Sensitivity

[ 0.44827586 0. 1. 0.3442623 0.36144578 1. ]

Specificity

[ 0.96261682 1. 0.85765125 1. 0.94007491 0.72302158]

Warning (from warnings module):

File "C:/Users/user/Desktop/Python code/NeuralNetwork/Vowel/RoughSet/Compare\_NN\_Fuzzified.py", line 300

Precision = TP/(TP+FP)

RuntimeWarning: invalid value encountered in true\_divide

Precision

[ 0.52 nan 0.63302752 1. 0.65217391 0.48322148]

Recall

**[ 0.44827586 0. 1. 0.3442623 0.36144578 1. ]**

Áccuracy

[ 0.92 0.89714286 0.88571429 0.88571429 0.80285714 0.78 ] =85.8

FScore

[ 0.48148148 nan 0.7752809 0.51219512 0.46511628 0.65158371]

MLP with no encoding

Epochs=80

Confusion Matrix

[[ 8 9 0 0 11 1]

[ 0 32 0 0 2 2]

[ 0 0 69 0 0 0]

[ 0 0 0 54 0 7]

[ 1 0 41 0 28 13]

[ 0 0 0 0 0 72]]

False Positives

[ 1 9 41 0 13 23]

False Negetives

[21 4 0 7 55 0]

True Positives

[ 8 32 69 54 28 72]

True Negetives

[320 305 240 289 254 255]

Sensitivity

[ 0.27586207 0.88888889 1. 0.8852459 0.3373494 1. ]

Specificity

[ 0.99688474 0.97133758 0.85409253 1. 0.95131086 0.91726619]

Precision

[ 0.88888889 0.7804878 0.62727273 1. 0.68292683 0.75789474]

Recall

[ 0.27586207 0.88888889 1. 0.8852459 0.3373494 1. ]

Áccuracy

[ 0.93714286 0.96285714 0.88285714 0.98 0.80571429 0.93428571] = 91.3

FScore

[ 0.42105263 0.83116883 0.77094972 0.93913043 0.4516129 0.86227545]

Observation II MLP with no encoding

No of epochs = 90, other parameters are same

confusion matrix

[[10 11 0 0 8 0]

[ 2 32 0 0 0 2]

[ 0 0 68 0 1 0]

[ 0 0 0 54 0 7]

[ 1 0 41 0 28 13]

[ 0 0 0 0 0 72]]

False Positives

[ 3 11 41 0 9 22]

False Negetives

[19 4 1 7 55 0]

True Positives

[10 32 68 54 28 72]

True Negetives

[318 303 240 289 258 256]

Sensitivity

[ 0.34482759 0.88888889 0.98550725 0.8852459 0.3373494 1. ]

Specificity

[ 0.99065421 0.96496815 0.85409253 1. 0.96629213 0.92086331]

Precision

[ 0.76923077 0.74418605 0.62385321 1. 0.75675676 0.76595745]

Recall

**[ 0.34482759 0.88888889 0.98550725 0.8852459 0.3373494 1. ]**

Áccuracy

[ 0.93714286 0.95714286 0.88 0.98 0.81714286 0.93714286] = 91.33

FScore

[ 0.47619048 0.81012658 0.76404494 0.93913043 0.46666667 0.86746988]

Observation III, MLP with no encoding

No of Epochs = 100, other parameters are same

[[11 11 0 0 7 0]

[ 2 32 0 0 0 2]

[ 0 0 68 0 1 0]

[ 0 0 0 55 0 6]

[ 2 0 43 0 26 12]

[ 0 0 0 2 0 70]]

False Positives

[ 4 11 43 2 8 20]

False Negetives

[18 4 1 6 57 2]

True Positives

[11 32 68 55 26 70]

True Negetives

[317 303 238 287 259 258]

Sensitivity

[ 0.37931034 0.88888889 0.98550725 0.90163934 0.31325301 0.97222222]

Specificity

[ 0.98753894 0.96496815 0.84697509 0.99307958 0.97003745 0.92805755]

Precision

[ 0.73333333 0.74418605 0.61261261 0.96491228 0.76470588 0.77777778]

Recall

**[ 0.37931034 0.88888889 0.98550725 0.90163934 0.31325301 0.97222222]**

Áccuracy

[ 0.93714286 0.95714286 0.87428571 0.97714286 0.81428571 0.93714286] = 91

FScore

[ 0.5 0.81012658 0.75555556 0.93220339 0.44444444 0.86419753]

Observation IV MLP with no encoding

Epochs = 120

confusion matrix

[[ 7 15 0 0 7 0]

[ 2 32 0 0 0 2]

[ 0 0 68 0 1 0]

[ 0 0 0 55 0 6]

[ 3 0 44 0 24 12]

[ 0 0 0 3 0 69]]

False Positives

[ 5 15 44 3 8 20]

False Negetives

[22 4 1 6 59 3]

True Positives

[ 7 32 68 55 24 69]

True Negetives

[316 299 237 286 259 258]

Sensitivity

[ 0.24137931 0.88888889 0.98550725 0.90163934 0.28915663 0.95833333]

Specificity

[ 0.98442368 0.9522293 0.84341637 0.98961938 0.97003745 0.92805755]

Precision

[ 0.58333333 0.68085106 0.60714286 0.94827586 0.75 0.7752809 ]

Recall

**[ 0.24137931 0.88888889 0.98550725 0.90163934 0.28915663 0.95833333]**

Áccuracy

[ 0.92285714 0.94571429 0.87142857 0.97428571 0.80857143 0.93428571] = 90.5

FScore

[ 0.34146341 0.77108434 0.75138122 0.92436975 0.4173913 0.85714286]

Epochs = 150 (MLP with no encoding)

Confusion matrix

[[ 7 15 0 0 7 0]

[ 2 32 0 0 0 2]

[ 0 0 68 0 1 0]

[ 0 0 0 55 0 6]

[ 3 0 44 0 24 12]

[ 0 0 0 3 0 69]]

False Positives

[ 5 15 44 3 8 20]

False Negetives

[22 4 1 6 59 3]

True Positives

[ 7 32 68 55 24 69]

True Negetives

[316 299 237 286 259 258]

Sensitivity

[ 0.24137931 0.88888889 0.98550725 0.90163934 0.28915663 0.95833333]

Specificity

[ 0.98442368 0.9522293 0.84341637 0.98961938 0.97003745 0.92805755]

Precision

[ 0.58333333 0.68085106 0.60714286 0.94827586 0.75 0.7752809 ]

Recall

[ 0.24137931 0.88888889 0.98550725 0.90163934 0.28915663 0.95833333]

Áccuracy

[ 0.92285714 0.94571429 0.87142857 0.97428571 0.80857143 0.93428571] = 90.5

FScore

[ 0.34146341 0.77108434 0.75138122 0.92436975 0.4173913 0.85714286]

**MLP with initial knowledge encoding, set of parameters are same**

Epochs = 35

12 3 0 0 11 3

2 2 0 0 2 30

0 0 67 0 2 0

0 0 0 53 0 8

0 0 25 0 45 13

0 0 0 0 0 72

False Positives

[ 2 3 25 0 15 54]

False Negetives

[17 34 2 8 38 0]

True Positives

[12 2 67 53 45 72]

True Negetives

[319 311 256 289 252 224]

Sensitivity

[ 0.4137931 0.05555556 0.97101449 0.86885246 0.54216867 1. ]

Specificity

[ 0.99376947 0.99044586 0.91103203 1. 0.94382022 0.8057554 ]

Precision

[ 0.85714286 0.4 0.72826087 1. 0.75 0.57142857]

Recall

[ 0.4137931 0.05555556 0.97101449 0.86885246 0.54216867 1. ]

Áccuracy

[ 0.94571429 0.89428571 0.92285714 0.97714286 0.84857143 0.84571429]

FScore

[ 0.55813953 0.09756098 0.83229814 0.92982456 0.62937063 0.72727273]

**MLP with initial knowledge encoding, set of parameters are same**

Epochs =40

10 6 0 0 11 2

1 27 0 0 2 6

0 0 67 0 2 0

0 0 0 53 0 8

1 0 28 0 42 12

0 0 0 0 0 72

False Positives

[ 2 6 28 0 15 28]

False Negetives

[19 9 2 8 41 0]

True Positives

[10 27 67 53 42 72]

True Negetives

[319 308 253 289 252 250]

Sensitivity

[ 0.34482759 0.75 0.97101449 0.86885246 0.5060241 1. ]

Specificity

[ 0.99376947 0.98089172 0.90035587 1. 0.94382022 0.89928058]

Precision

[ 0.83333333 0.81818182 0.70526316 1. 0.73684211 0.72 ]

Recall

[ 0.34482759 0.75 0.97101449 0.86885246 0.5060241 1. ]

Áccuracy

[ 0.94 0.95714286 0.91428571 0.97714286 0.84 0.92 ]

FScore

[ 0.48780488 0.7826087 0.81707317 0.92982456 0.6 0.8372093 ]

**MLP with initial knowledge encoding, set of parameters are same**

Epochs = 50

3 15 0 0 11 0

0 32 0 0 2 2

0 0 67 0 2 0

0 0 0 54 0 7

1 0 31 0 39 12

0 0 0 1 0 71

False Positives

[ 1 15 31 1 15 21]

False Negetives

[26 4 2 7 44 1]

True Positives

[ 3 32 67 54 39 71]

True Negetives

[320 299 250 288 252 257]

Sensitivity

[ 0.10344828 0.88888889 0.97101449 0.8852459 0.46987952 0.98611111]

Specificity

[ 0.99688474 0.9522293 0.88967972 0.99653979 0.94382022 0.92446043]

Precision

[ 0.75 0.68085106 0.68367347 0.98181818 0.72222222 0.77173913]

Recall

[ 0.10344828 0.88888889 0.97101449 0.8852459 0.46987952 0.98611111]

Áccuracy

[ 0.92285714 0.94571429 0.90571429 0.97714286 0.83142857 0.93714286]= 91.5

FScore

[ 0.18181818 0.77108434 0.80239521 0.93103448 0.56934307 0.86585366]

**MLP with initial knowledge encoding, set of parameters are same**

Epochs = 80

5 15 0 0 9 0

1 32 0 0 1 2

0 0 67 0 2 0

0 0 0 55 0 6

2 0 39 0 30 12

0 0 0 4 0 68

False Positives

[ 3 15 39 4 12 20]

False Negetives

[24 4 2 6 53 4]

True Positives

[ 5 32 67 55 30 68]

True Negetives

[318 299 242 285 255 258]

Sensitivity

[ 0.17241379 0.88888889 0.97101449 0.90163934 0.36144578 0.94444444]

Specificity

[ 0.99065421 0.9522293 0.86120996 0.98615917 0.95505618 0.92805755]

Precision

[ 0.625 0.68085106 0.63207547 0.93220339 0.71428571 0.77272727]

Recall

[ 0.17241379 0.88888889 0.97101449 0.90163934 0.36144578 0.94444444]

Áccuracy

[ 0.92285714 0.94571429 0.88285714 0.97142857 0.81428571 0.93142857] = 90.8

FScore

[ 0.27027027 0.77108434 0.76571429 0.91666667 0.48 0.85 ]

**MLP with initial knowledge encoding, set of parameters are same**

Epochs = 90

5 15 0 0 9 0

1 32 0 0 1 2

0 0 67 0 2 0

0 0 0 55 0 6

2 0 41 0 28 12

0 0 0 5 0 67

False Positives

[ 3 15 41 5 12 20]

False Negetives

[24 4 2 6 55 5]

True Positives

[ 5 32 67 55 28 67]

True Negetives

[318 299 240 284 255 258]

Sensitivity

[ 0.17241379 0.88888889 0.97101449 0.90163934 0.3373494 0.93055556]

Specificity

[ 0.99065421 0.9522293 0.85409253 0.98269896 0.95505618 0.92805755]

Precision

[ 0.625 0.68085106 0.62037037 0.91666667 0.7 0.77011494]

Recall

[ 0.17241379 0.88888889 0.97101449 0.90163934 0.3373494 0.93055556]

Áccuracy

[ 0.92285714 0.94571429 0.87714286 0.96857143 0.80857143 0.92857143] =90.2

FScore

[ 0.27027027 0.77108434 0.75706215 0.90909091 0.45528455 0.8427673 ]

**MLP with initial knowledge encoding, set of parameters are same**

epochs = 100

7 15 0 0 7 0

2 32 0 0 0 2

0 0 67 0 2 0

0 0 0 55 0 6

3 0 41 0 28 11

0 0 0 6 0 66

False Positives

[ 5 15 41 6 9 19]

False Negetives

[22 4 2 6 55 6]

True Positives

[ 7 32 67 55 28 66]

True Negetives

[316 299 240 283 258 259]

Sensitivity

[ 0.24137931 0.88888889 0.97101449 0.90163934 0.3373494 0.91666667]

Specificity

[ 0.98442368 0.9522293 0.85409253 0.97923875 0.96629213 0.93165468]

Precision

[ 0.58333333 0.68085106 0.62037037 0.90163934 0.75675676 0.77647059]

Recall

[ 0.24137931 0.88888889 0.97101449 0.90163934 0.3373494 0.91666667]

Áccuracy

[ 0.92285714 0.94571429 0.87714286 0.96571429 0.81714286 0.92857143]= 90.3

FScore

[ 0.34146341 0.77108434 0.75706215 0.90163934 0.46666667 0.84076433]

**MLP with initial knowledge encoding, set of parameters are same**

epochs =120

confusion matrix

7 15 0 0 7 0

2 32 0 0 0 2

0 0 67 0 2 0

0 0 0 59 0 2

4 0 37 0 31 11

0 0 0 13 0 59

False Positives

[ 6 15 37 13 9 15]

False Negetives

[22 4 2 2 52 13]

True Positives

[ 7 32 67 59 31 59]

True Negetives

[315 299 244 276 258 263]

Sensitivity

[ 0.24137931 0.88888889 0.97101449 0.96721311 0.37349398 0.81944444]

Specificity

[ 0.98130841 0.9522293 0.8683274 0.9550173 0.96629213 0.94604317]

Precision

[ 0.53846154 0.68085106 0.64423077 0.81944444 0.775 0.7972973 ]

Recall

[ 0.24137931 0.88888889 0.97101449 0.96721311 0.37349398 0.81944444]

Áccuracy

[ 0.92 0.94571429 0.88857143 0.95714286 0.82571429 0.92 ] = 90.5

FScore

[ 0.33333333 0.77108434 0.77456647 0.88721805 0.50406504 0.80821918]

**Method 1 = MLP with initial knowledge encoding, set of parameters are same**

Epochs = 150

[[ 7 15 0 0 7 0]

[ 2 32 0 0 0 2]

[ 0 0 68 0 1 0]

[ 0 0 0 55 0 6]

[ 3 0 44 0 24 12]

[ 0 0 0 3 0 69]]

False Positives

[ 5 15 44 3 8 20]

False Negetives

[22 4 1 6 59 3]

True Positives

[ 7 32 68 55 24 69]

True Negetives

[316 299 237 286 259 258]

Sensitivity

[ 0.24137931 0.88888889 0.98550725 0.90163934 0.28915663 0.95833333]

Specificity

[ 0.98442368 0.9522293 0.84341637 0.98961938 0.97003745 0.92805755]

Precision

[ 0.58333333 0.68085106 0.60714286 0.94827586 0.75 0.7752809 ]

Recall

[ 0.24137931 0.88888889 0.98550725 0.90163934 0.28915663 0.95833333]

Áccuracy

[ 0.92285714 0.94571429 0.87142857 0.97428571 0.80857143 0.93428571] 90.5

FScore

[ 0.34146341 0.77108434 0.75138122 0.92436975 0.4173913 0.85714286]

**Method II MLP with initial knowledge encoding, set of parameters are same**

**Epochs 15**

14 2 0 0 19 1

17 13 0 0 1 1

0 0 68 0 10 0

0 0 0 37 1 16

0 0 7 0 67 2

4 0 0 2 3 64

False Positives

[21 2 7 2 34 20]

False Negetives

[22 19 10 17 9 9]

True Positives

[14 13 68 37 67 64]

True Negetives

[292 315 264 293 239 256]

Sensitivity

[ 0.38888889 0.40625 0.87179487 0.68518519 0.88157895 0.87671233]

Specificity

[ 0.93290735 0.99369085 0.97416974 0.99322034 0.87545788 0.92753623]

Precision

[ 0.4 0.86666667 0.90666667 0.94871795 0.66336634 0.76190476]

Recall

[ 0.38888889 0.40625 0.87179487 0.68518519 0.88157895 0.87671233]

Áccuracy

[ 0.87679083 0.93982808 0.9512894 0.94555874 0.87679083 0.91690544]

FScore

[ 0.3943662 0.55319149 0.88888889 0.79569892 0.75706215 0.81528662]

**Method II MLP with initial knowledge encoding, set of parameters are same**

Neurons in hidden layer = 6

Neurons in input layer = 7

Neurons in output layer = 6

learning rate = 0.1

Training set = 60%

Epochs = 80

11 9 0 0 14 2

3 27 0 0 2 0

0 0 70 0 8 0

0 0 0 48 1 5

0 0 9 0 65 2

3 0 0 9 2 59

False Positives

[ 6 9 9 9 27 9]

False Negatives

[25 5 8 6 11 14]

True Positives

[11 27 70 48 65 59]

True Negatives

[307 308 262 286 246 267]

Sensitivity

[ 0.30555556 0.84375 0.8974359 0.88888889 0.85526316 0.80821918]

Specificity

[ 0.98083067 0.97160883 0.96678967 0.96949153 0.9010989 0.9673913 ]

Precision

[ 0.64705882 0.75 0.88607595 0.84210526 0.70652174 0.86764706]

Recall

[ 0.30555556 0.84375 0.8974359 0.88888889 0.85526316 0.80821918]

Áccuracy

[ 0.91117479 0.95988539 0.9512894 0.95702006 0.89111748 0.93409742]

FScore

[ 0.41509434 0.79411765 0.89171975 0.86486486 0.77380952 0.83687943]