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CS669: Pattern Recognition

GROUP-13
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INTRODUCTION –

In pattern recognition, machine learning and statistics, classification is the problem of identifying to which of a set of categories (sub-populations) a new observation belongs, on the basis of a training set of data containing observations (or instances) whose category membership is known. An example would be assigning a given email into "spam" or "non-spam" classes or assigning a diagnosis to a given patient as described by observed characteristics of the patient (gender, blood pressure, presence or absence of certain symptoms, etc.).

Problem Statement:

- Classifiers to be used –
  - Classification of several types of data using **KNN** classifier using **DTW** for **different number of neighbor** size and observe the results.
  - Classification of several types of data using Discrete **HMM** classifier using **Baum-Welch algorithm** for **different number of states and symbols** and observe the results.

- Data types provided –
  - Image data
    It has three classes. Each image has been divided into 36 segments and each of these segments has 23 attributes.
  - Speech data
    It has three classes. Each image has been divided into varying number of segments and each of these segments has 39 attributes.

- Learning Objective –
  - Observe performance **Accuracy** and **Confusion Matrix** from different classifiers for the provided data sets.
  - Conclude inferences from these observations.

CLASSIFIERS –

A **hidden Markov model** (**HMM**) is a statistical Markov model in which the system being modeled is assumed to be a Markov process with unobserved (*hidden*) states. A HMM can be presented as the simplest dynamic Bayesian network. The mathematics behind the HMM was developed by L. E. Baum and coworkers.

In simpler Markov models (like a Markov chain), the state is directly visible to the observer, and therefore the state transition probabilities are the only parameters. In a *hidden* Markov model, the state is not directly visible, but output, dependent on the state, is visible. Each state has a probability distribution over the possible output tokens. Therefore, the sequence of tokens generated by an HMM gives some information about the sequence of states. Note that the adjective 'hidden' refers to the state sequence through which the model passes, not to the parameters of the model; the model is still referred to as a 'hidden' Markov model even if these parameters are known exactly.

Hidden Markov models are especially known for their application in temporal pattern recognition such as speech, handwriting, gesture recognition, part-of-speech tagging, musical score following, partial discharges and bioinformatics.

Maximum likelihood for the HMM

We define the elements of an HMM by specifying the following parameters:

N: The number of states in the model. The state of the model at time t is given by q_t, $1 \le q_t \le N$ and $1 \le t \le T$ where T is the length (number of frames) of the output observable symbol sequence.

M: The size of the codebook or the number of distinct observable symbols per state. Assume ot is one of all possible observable symbols for each state at time t, then $0 \le O_t \le M-1$

π_N: An N-element vector indicates the initial state probability. $\pi = \{\pi_i\}$, where $\pi_i = P(q_1=i)$, $1 \le i \le N$

A_{NxN}: An N x N matrix specifies the state-transition probability that the state will transit from state i to state j. $A = \{a_{ij}\}$ where $a_{ij} = P(q_t=j \mid q_t\text{-}1=i)$, $1 \le i, j \le N$ (6-24) and $a_{ij} \ge 0$, $\sum_{j=1}^{N} aij = 1$ $1 \le i \le N$

B_{MxN}: An M x N matrix represents the probability that the system will generate the observable symbol o_t at state j and at time t. $B = \{b_j(o_t)\}$ where $b_j(o_t) = P(O_t=o_t \mid q_t=j)$, $1 \le j \le N$, $0 \le o_t \le M-1$, and $b_j(o_t) \ge 0$, $1 \le j \le N$, and $\sum_{ot=1}^{M-1} bj(Ot) = 1$, $1 \le j \le N$

The complete parameter set λ of the discrete HMM is represented by one vector π and two matrices A and B
$\lambda = (\pi, A, B)$

In the E-step:

The likelihood function:

$$p(\mathbf{X}|\boldsymbol{\theta}) = \sum_{\mathbf{Z}} p(\mathbf{X}, \mathbf{Z}|\boldsymbol{\theta}).$$

Expectation of the logarithm of the complete-data likelihood function is:

$$Q(\boldsymbol{\theta}, \boldsymbol{\theta}^{\text{old}}) = \sum_{\mathbf{Z}} p(\mathbf{Z}|\mathbf{X}, \boldsymbol{\theta}^{\text{old}}) \ln p(\mathbf{X}, \mathbf{Z}|\boldsymbol{\theta}).$$

$$\begin{aligned} \gamma(\mathbf{z}_n) &= p(\mathbf{z}_n|\mathbf{X}, \boldsymbol{\theta}^{\text{old}}) \\ \xi(\mathbf{z}_{n-1}, \mathbf{z}_n) &= p(\mathbf{z}_{n-1}, \mathbf{z}_n|\mathbf{X}, \boldsymbol{\theta}^{\text{old}}). \end{aligned}$$

Where $\gamma(z_n)$ denotes the marginal posterior distribution of a latent variable z_n, and $\xi(z_{n-1}, z_n)$ denotes the joint posterior distribution of two successive latent variables.

In the M-step:

$$\begin{aligned} \pi_k &= \frac{\gamma(z_{1k})}{\sum_{j=1}^{K} \gamma(z_{1j})} \\ A_{jk} &= \frac{\sum_{n=2}^{N} \xi(z_{n-1,j}, z_{nk})}{\sum_{l=1}^{K} \sum_{n=2}^{N} \xi(z_{n-1,j}, z_{nl})}. \end{aligned}$$

The EM algorithm is initialized by choosing starting values for π and A.

♦ Dataset I: Scene image data corresponding to 3 different classes

A 23-dimensional feature vector is extracted from local blocks of an image for a particular scene. The 23-dimensional features include color histogram, edge directed histograms and entropy of wavelet coefficients. Each scene image is represented as a collection of 23-dimensional local feature vectors.

1) K-Nearest Neighbor Classifier using DTW –

- **K = 4**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	60	4	1
Class 2	22	51	0
Class 3	29	37	23

  - *Classification accuracy on test data*

Overall Accuracy: 0.590308
Class 1 Accuracy: 0.923077
Class 2 Accuracy: 0.698630
Class 3 Accuracy: 0.258427

- **K = 23**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	61	3	1
Class 2	19	54	0
Class 3	43	30	16

  - *Classification accuracy on test data*

Overall Accuracy: 0.577093
Class 1 Accuracy: 0.938462
Class 2 Accuracy: 0.739726
Class 3 Accuracy: 0.179775

- **K = 100**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	54	9	2
Class 2	9	63	1
Class 3	41	23	25

  - *Classification accuracy on test data*

Overall Accuracy: 0.625551
Class 1 Accuracy: 0.830769
Class 2 Accuracy: 0.863014
Class 3 Accuracy: 0.280899

- **K = 243**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	41	14	10
Class 2	5	67	1
Class 3	26	22	41

  - *Classification accuracy on test data*

Overall Accuracy: 0.656388
Class 1 Accuracy: 0.630769
Class 2 Accuracy: 0.917808
Class 3 Accuracy: 0.460674

- **K = 325**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	23	21	21
Class 2	3	67	3
Class 3	16	21	52

- *Classification accuracy on test data*

Overall Accuracy: 0.625551
Class 1 Accuracy: 0.353846
Class 2 Accuracy: 0.917808
Class 3 Accuracy: 0.584270

- **K = 430**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	5	28	32
Class 2	2	67	4
Class 3	7	22	60

  - *Classification accuracy on test data*

Overall Accuracy: 0.581498
Class 1 Accuracy: 0.076923
Class 2 Accuracy: 0.917808
Class 3 Accuracy: 0.674157

- **K = 550**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	0	14	51
Class 2	0	53	20
Class 3	0	11	78

  - *Classification accuracy on test data*

Overall Accuracy: 0.577093
Class 1 Accuracy: 0.000000
Class 2 Accuracy: 0.726027
Class 3 Accuracy: 0.876404

- **K = 681**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	0	0	65
Class 2	0	0	73
Class 3	0	0	89

  - *Classification accuracy on test data*

Overall Accuracy: 0.392070
Class 1 Accuracy: 0.000000
Class 2 Accuracy: 0.000000
Class 3 Accuracy: 1.000000

2) Discrete Hidden Markov model Classifier –

- **N = 2 & M = 8**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	19	11	35
Class 2	15	50	8
Class 3	24	20	45

  - *Classification accuracy on test data*

Overall Accuracy – 50.2203
Classifier Accuracy for class 1 – 29.2308
Classifier Accuracy for class 2 – 68.4932
Classifier Accuracy for class 3 – 50.5618

- **N = 2 & M = 32**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	34	11	20
Class 2	9	55	9
Class 3	20	32	37

  - *Classification accuracy on test data*

Overall Accuracy – 55.5066
Classifier Accuracy for class 1 – 52.3077
Classifier Accuracy for class 2 – 75.3425
Classifier Accuracy for class 3 – 41.5730

- **N = 2 & M = 64**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	34	12	19
Class 2	4	64	5
Class 3	15	34	40

  - *Classification accuracy on test data*

Overall Accuracy: 0.607930
Classifier Accuracy for class 1 - 0.523077
Classifier Accuracy for class 2 – 0.876712
Classifier Accuracy for class 3 – 0.449438

- **N = 2 & M = 128**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	27	9	29
Class 2	4	60	9
Class 3	13	24	52

  - *Classification accuracy on test data*

Overall Accuracy – 61.2335
Classifier Accuracy for class 1 – 41.5385
Classifier Accuracy for class 2 – 82.1918
Classifier Accuracy for class 3 – 58.4270

- **N = 4 & M = 8**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	15	20	30
Class 2	7	62	4
Class 3	18	40	31

  - *Classification accuracy on test data*

Overall Accuracy – 47.5771
Classifier Accuracy for class 1 – 23.0769
Classifier Accuracy for class 2 – 84.9315
Classifier Accuracy for class 3 – 34.8315

- **N = 4 & M = 32**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	51	5	9
Class 2	13	50	10
Class 3	31	21	37

  - *Classification accuracy on test data*

Overall Accuracy – 60.7930
Classifier Accuracy for class 1 – 78.4615
Classifier Accuracy for class 2 – 68.4932
Classifier Accuracy for class 3 – 41.5730

- **N = 4 & M = 64**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	43	9	13
Class 2	5	57	11
Class 3	15	21	53

  - *Classification accuracy on test data*

Overall Accuracy – 0.674009
Classifier Accuracy for class 1 – 0.661538
Classifier Accuracy for class 2 – 0.780822
Classifier Accuracy for class 3 – 0.674009

- **N = 4 & M = 128**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	39	7	19
Class 2	6	59	8
Class 3	14	24	51

  - *Classification accuracy on test data*

Overall Accuracy – 65.6388
Classifier Accuracy for class 1 – 60.0000
Classifier Accuracy for class 2 – 80.8219
Classifier Accuracy for class 3 – 57.3034

- **N = 8 & M = 8**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	21	21	23
Class 2	6	63	4
Class 3	18	44	27

  - *Classification accuracy on test data*

Overall Accuracy – 48.8987
Classifier Accuracy for class 1 – 32.3077
Classifier Accuracy for class 2 – 86.3014
Classifier Accuracy for class 3 – 30.3371

- **N = 8 & M = 32**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	33	14	18
Class 2	6	61	6
Class 3	19	37	33

  - *Classification accuracy on test data*

Overall Accuracy – 55.9471
Classifier Accuracy for class 1 – 50.7692
Classifier Accuracy for class 2 – 83.5616
Classifier Accuracy for class 3 – 37.0787

- **N = 8 & M = 64**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	34	12	19
Class 2	4	64	5
Class 3	15	34	40

  - *Classification accuracy on test data*

Overall Accuracy: 0.607930
Class 1 Accuracy: 0.523077
Class 2 Accuracy: 0.876712
Class 3 Accuracy: 0.449438

- **N = 8 & M = 128**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	35	11	19
Class 2	7	58	8
Class 3	18	18	53

  - *Classification accuracy on test data*

Overall Accuracy – 64.3172
Classifier Accuracy for class 1 – 53.862
Classifier Accuracy for class 2 – 79.4521
Classifier Accuracy for class 3 – 59.5506

♦ **Dataset II: Spoken digit dataset corresponding to 3 isolated digit utterances**

The 39-dimensional Mel frequency cepstral coefficient (MFCC) features have been extracted frame by frame from utterances for a particular digit spoken by multiple people.

1) KNN Classifier using DTW –

- **K = 4**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	40	0	0
Class 2	0	40	0
Class 3	0	0	40

  - *Classification accuracy on test data*

Overall Accuracy: 1.000000
Class 1 Accuracy: 1.000000
Class 2 Accuracy: 1.000000
Class 3 Accuracy: 1.000000

- **K = 20**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	40	0	0
Class 2	0	40	0
Class 3	0	0	40

  - *Classification accuracy on test data*

Overall Accuracy: 1.000000
Class 1 Accuracy: 1.000000
Class 2 Accuracy: 1.000000
Class 3 Accuracy: 1.000000

- **K = 100**

- *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	32	0	8
Class 2	0	40	0
Class 3	0	0	40

- *Classification accuracy on test data*

Overall Accuracy: 0.933333
Class 1 Accuracy: 0.800000
Class 2 Accuracy: 1.000000
Class 3 Accuracy: 1.000000

- **K = 140**

- *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	24	0	16
Class 2	0	40	0
Class 3	0	0	40

- *Classification accuracy on test data*

Overall Accuracy: 0.866667
Class 1 Accuracy: 0.600000
Class 2 Accuracy: 1.000000
Class 3 Accuracy: 1.000000

- **K = 212**

- *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	12	0	28
Class 2	0	39	1
Class 3	0	0	40

- *Classification accuracy on test data*

Overall Accuracy: 0.758333
Class 1 Accuracy: 0.300000
Class 2 Accuracy: 0.975000
Class 3 Accuracy: 1.000000

- **K = 256**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	8	0	32
Class 2	0	33	7
Class 3	0	0	40

  - *Classification accuracy on test data*

Overall Accuracy: 0.675000
Class 1 Accuracy: 0.200000
Class 2 Accuracy: 0.825000
Class 3 Accuracy: 1.000000

- **K = 300**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	2	0	38
Class 2	0	39	1
Class 3	0	0	40

  - *Classification accuracy on test data*

Overall Accuracy: 0.675000
Class 1 Accuracy: 0.050000
Class 2 Accuracy: 0.975000
Class 3 Accuracy: 1.000000

2) Discrete Hidden Markov model Classifier –

- **N = 2 & M = 8**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	40	0	0
Class 2	0	40	0
Class 3	0	0	40

  - *Classification accuracy on test data*

Overall Accuracy – 100.0000
Classifier Accuracy for class 1 – 100.0000
Classifier Accuracy for class 2 – 100.0000
Classifier Accuracy for class 3 – 100.0000

- **N = 2 & M = 32**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	**CLASS 1**	**CLASS 2**	**CLASS 3**
Actual Class ⇩			
Class 1	40	0	0
Class 2	0	40	0
Class 3	0	0	40

  - *Classification accuracy on test data*

Overall Accuracy – 100.0000
Classifier Accuracy for class 1 – 100.0000
Classifier Accuracy for class 2 – 100.0000
Classifier Accuracy for class 3 – 100.0000

- **N = 2 & M = 64**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	CLASS 1	CLASS 2	CLASS 3
Actual Class ⇩			
Class 1	40	0	0
Class 2	2	38	0
Class 3	0	0	40

  - *Classification accuracy on test data*

Overall Accuracy – 98.3333
Classifier Accuracy for class 1 – 100.0000
Classifier Accuracy for class 2 – 95.0000
Classifier Accuracy for class 3 – 100.0000

- **N = 2 & M = 128**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨	CLASS 1	CLASS 2	CLASS 3
Actual Class ⇩			
Class 1	40	0	0
Class 2	2	37	1
Class 3	0	0	40

  - *Classification accuracy on test data*

Overall Accuracy – 97.5000
Classifier Accuracy for class 1 – 100.0000
Classifier Accuracy for class 2 – 92.5000
Classifier Accuracy for class 3 – 100.0000

- **N = 4 & M = 8**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	40	0	0
Class 2	0	40	0
Class 3	0	0	40

  - *Classification accuracy on test data*

Overall Accuracy – 100.0000
Classifier Accuracy for class 1 – 100.0000
Classifier Accuracy for class 2 – 100.0000
Classifier Accuracy for class 3 – 100.0000

- **N = 4 & M = 32**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	40	0	0
Class 2	0	40	0
Class 3	0	0	40

  - *Classification accuracy on test data*

Overall Accuracy – 100.0000
Classifier Accuracy for class 1 – 100.0000
Classifier Accuracy for class 2 – 100.0000
Classifier Accuracy for class 3 – 100.0000

- **N = 4 & M = 64**
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Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	40	0	0
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Class 3	0	0	40

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Overall Accuracy – 98.3333
Classifier Accuracy for class 1 – 100.0000
Classifier Accuracy for class 2 – 95.0000
Classifier Accuracy for class 3 – 100.0000

- **N = 4 & M = 128**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	40	0	0
Class 2	1	37	2
Class 3	0	0	40

  - *Classification accuracy on test data*

Overall Accuracy – 97.5000
Classifier Accuracy for class 1 – 100.0000
Classifier Accuracy for class 2 – 92.5000
Classifier Accuracy for class 3 – 100.0000

- **N = 6 & M = 8**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	40	0	0
Class 2	4	36	0
Class 3	3	0	37

  - *Classification accuracy on test data*

Overall Accuracy – 94.1667
Classifier Accuracy for class 1 – 100.0000
Classifier Accuracy for class 2 – 90.0000
Classifier Accuracy for class 3 – 92.5000

- **N = 6 & M = 32**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	40	0	0
Class 2	0	40	0
Class 3	0	0	40

  - *Classification accuracy on test data*

Overall Accuracy – 100.0000
Classifier Accuracy for class 1 – 100.0000
Classifier Accuracy for class 2 – 100.0000
Classifier Accuracy for class 3 – 100.0000

- **N = 6 & M = 64**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
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Classifier Accuracy for class 1 – 100.0000
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Classifier Accuracy for class 3 – 100.0000

- **N = 6 & M = 128**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	40	0	0
Class 2	1	37	2
Class 3	0	0	40

  - *Classification accuracy on test data*

Overall Accuracy – 97.5000
Classifier Accuracy for class 1 – 100.0000
Classifier Accuracy for class 2 – 92.5000
Classifier Accuracy for class 3 – 100.0000

- **N = 8 & M = 8**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	40	0	0
Class 2	1	39	0
Class 3	3	0	37

  - *Classification accuracy on test data*

Overall Accuracy – 96.6667
Classifier Accuracy for class 1 – 100.0000
Classifier Accuracy for class 2 – 97.5000
Classifier Accuracy for class 3 – 92.5000

- **N = 8 & M = 32**
  - *Confusion Matrix based on performance for test data*

Predicted Class ⇨ / Actual Class ⇩	CLASS 1	CLASS 2	CLASS 3
Class 1	40	0	0
Class 2	0	40	0
Class 3	0	0	40

  - *Classification accuracy on test data*

Overall Accuracy – 100.0000
Classifier Accuracy for class 1 – 100.0000
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