
Assignment 04

PATTERN RECOGNITION
CS 6690

GROUP 24

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Abstract

Table 1: Model Accuracy Table

Dataset	Accuracy (in %)
Isolated Digit	96.1
Connected Digits	71.4
Handwriting Isolated	86.5
DTW Digit	98.0

1 Digit Dataset

1.1 Isolated Digit Dataset

Assigned Digits : 1 (one), 2 (two), 5 (five). Several instances of each digits pronunciations were used to train corresponding HMM models.

Accuracy on isolated digit data recorded is **98%** using 12 clusters.

Table 2: Isolated Digit Confusion Matrix Table @K=12

	1	2	5
1	17	0	0
2	0	16	0
5	0	1	17

Accuracy for **Digit '1'** = 100.0%

Accuracy for **Digit '2'** = 94.1%

Accuracy for **Digit '5'** = 100.0%

Total Accuracy = 98.0%

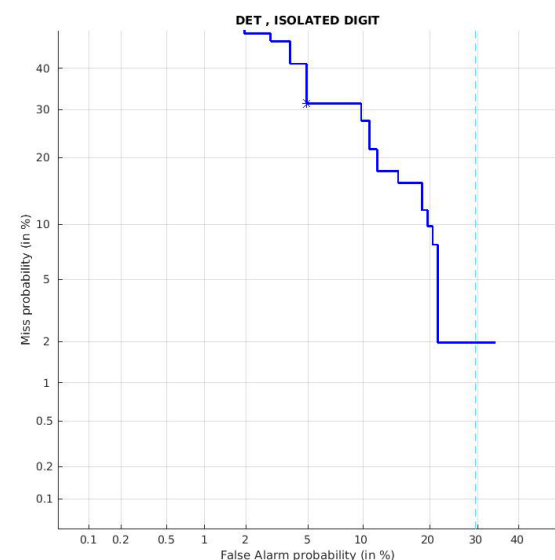
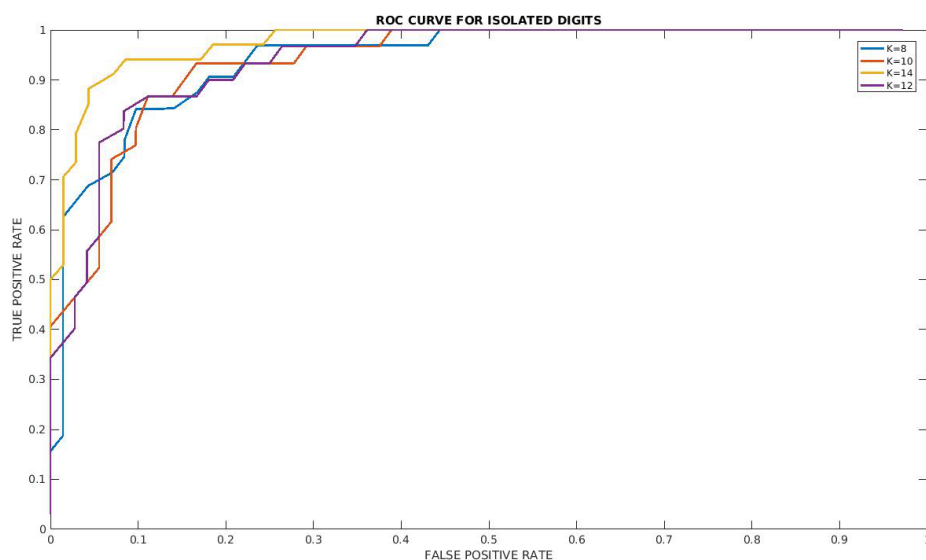


Figure 1: Comparing ROC Curves for Cluster Centers = 8, 10, 12 and 14 & DET Curve using 12 Cluster Centers and 10 state HMM

On Monotonically increasing number of Cluster centers did not necessarily improve accuracy.

1.2 Connected Digit Sequences

Assigned sequences were 2 and 3 length combinations of the digits 1,2,5. HMMs for identifying all 2 and 3 digit sequences were made. Each model was tested on each test data. For the known test data, accuracy was 71.14%, with 10 out of 14 test data being successfully identified. These were the results:

Test Sequence	1-1-1	1-1	1-2-1	1-2	1-5	2-1-2	2-1	2-2	2-5	5-1-2	5-1	5-2-5	5-2	5-5
Identified Sequence	1-1	1-1	5-1	1-2	1-5	2-2-1	2-1	2-2	2-5	5-1-2	5-1	5-5-5	5-2	5-5

A second set of data was provided for identification, the following were it's results:

Sequence Name	1-9-9	2-0-0	2-0-1	2-0-2	2-0-3	2-0-4	2-0-5	2-0-6	2-0-7	2-0-8	2-0-9	2-1-0
Predicted Sequence	1-1	1-2-2	1-1-1	1-1-5	1-5-1	2-2-1	2-5-5	2-5-2	5-1	5-2-5	5-2	5-5

2 Handwriting Dataset

2.1 Isolated Characters

Assigned characters were : a , chA , tA.

The following features were extracted and utilized.

Feature Extraction:

Normalizing Coordinates:

$$x_n = \frac{x_n^s - x_{min}^s}{x_{max}^s - x_{min}^s} \quad \text{and} \quad y_n = \frac{y_n^s - y_{min}^s}{y_{max}^s - y_{min}^s}$$

Deviation Features:

$$v_{1xn} = \frac{(x_n - \mu_x)}{\sigma_y} \quad \text{and} \quad v_{1yn} = \frac{(y_n - \mu_y)}{\sigma_x}$$

$$\mu_x = \frac{1}{N} \sum_{n=1}^N x_n \quad \mu_y = \frac{1}{N} \sum_{n=1}^N y_n$$

$$\sigma_x = \sqrt{\frac{1}{N-1} \sum_{n=1}^N (\mu_x - x_n)^2} \quad \sigma_y = \sqrt{\frac{1}{N-1} \sum_{n=1}^N (\mu_y - y_n)^2}$$

$$v_{2xn} = \frac{(x_n - \mu_x)}{\sigma_{xy}} \quad \text{and} \quad v_{2yn} = \frac{(y_n - \mu_y)}{\sigma_{xy}}$$

$$\sigma_{xy} = \sqrt{\sum_{n=1}^N (\mu_x - x_n)^2 + (\mu_y - y_n)^2}$$

Trajectory Features:

$$\theta_n = \tan^{-1} \left(\frac{y_n}{x_n} \right)$$

Table 3: Confusion Matrix for Isolated Handwritten Characters

	a	chA	tA
a	26	0	1
chA	0	26	3
tA	4	4	25

Accuracy for Digit 'a' = 86.7%
 Accuracy for Digit 'chA' = 86.7%
 Accuracy for Digit 'tA' = 86.2%
Total Accuracy = 86.5%

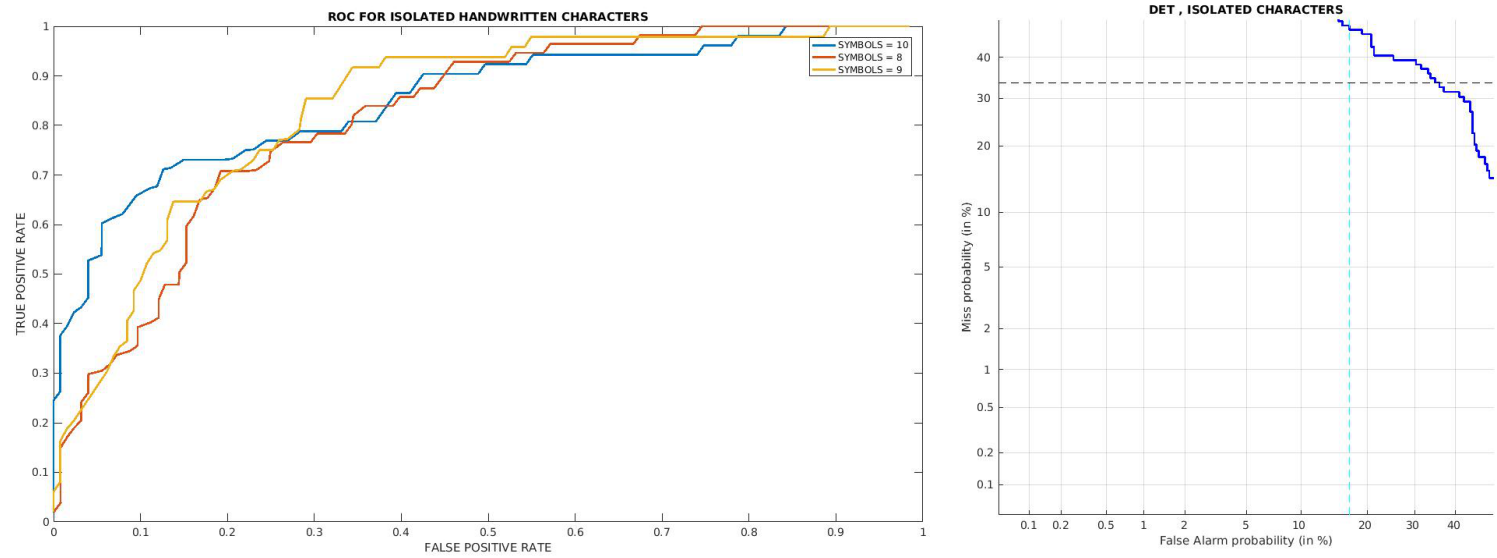


Figure 2: ROC and DET Plot for Handwritten Isolated Characters with fixed @K=12 and different States of HMM

Highest Accuracy obtained = **86.5%**, when 12 cluster centers were used in K-Means and 10-States, 10-Symbols Hidden Markov Model was used.

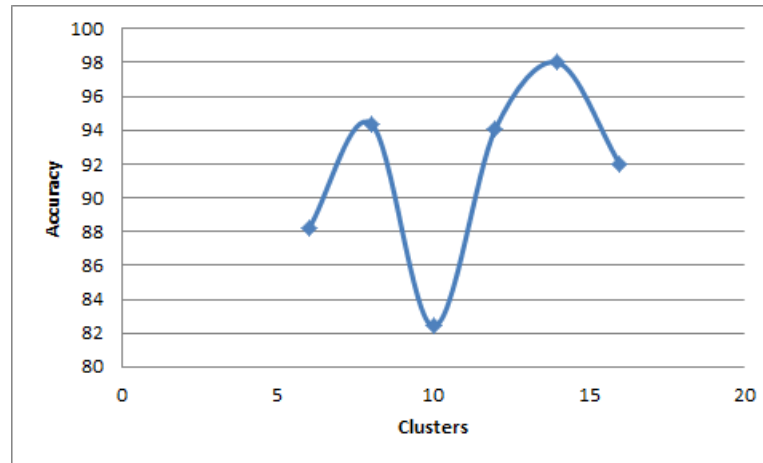


Figure 3: Variation of accuracy with clusters with 8 states HMM

2.2 Continuous Characters

Test data had three unknown sequences using the characters 'a', 'chA', 'tA'. The following shows the sample data, and the corresponding classification

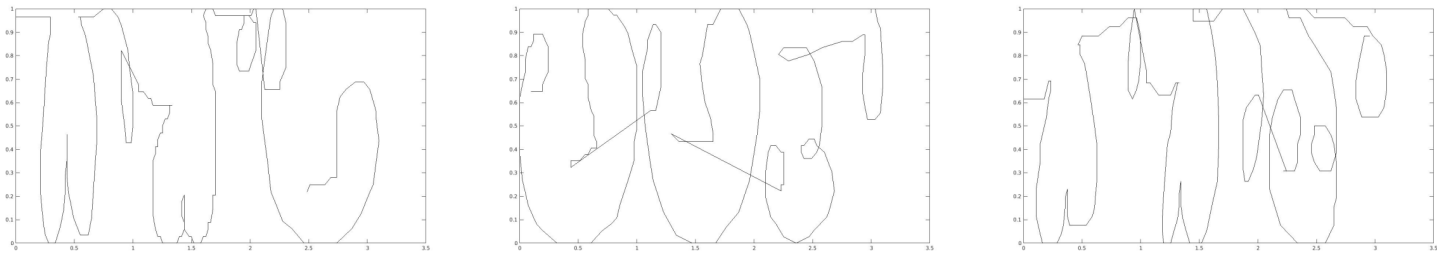


Figure 4: Sample Data Characters

They are correspondingly classified as:

a-chA-a a-a-tA tA-tA-tA

3 Dynamic Time Warping

Templates were created for the individual digits using the training data. For a given input utterance of a specific digit ie test data, its minimum distance to training templates was calculated using Dynamic Time Warping. The template offering the smallest distance was chosen as the target. An accuracy of **98%** was achieved

Table 4: DTW Confusion Matrix

	1	2	5
1	17	0	1
2	0	17	0
5	0	0	16

Accuracy for **Digit '1'** = 100.0%

Accuracy for **Digit '2'** = 100.0%

Accuracy for **Digit '5'** = 94.1%

Total Accuracy = 98.0%

4 Inferences

1. Although isolated digit recognition had high accuracy, the same was not achieved for continuous digits, since even if one digit in sequence was misclassified, the entire sequence is misclassified. The same is the case with isolated and continuous handwritten character sequences.