

DSP - Digital Signal Processing

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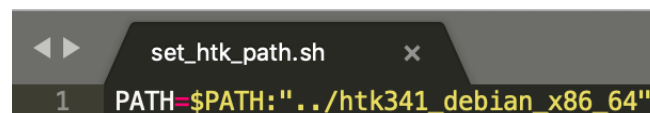
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DSP

Assignment 2-1 HMM Training and Testing

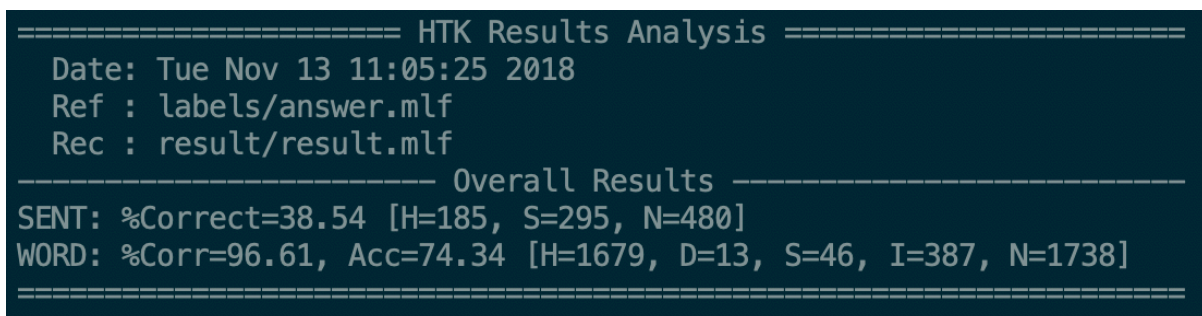
Part 1 - Run Baseline

Following the steps in homework description, set path to:



```
set_htk_path.sh
1 PATH=$PATH:../htk341_debian_x86_64
```

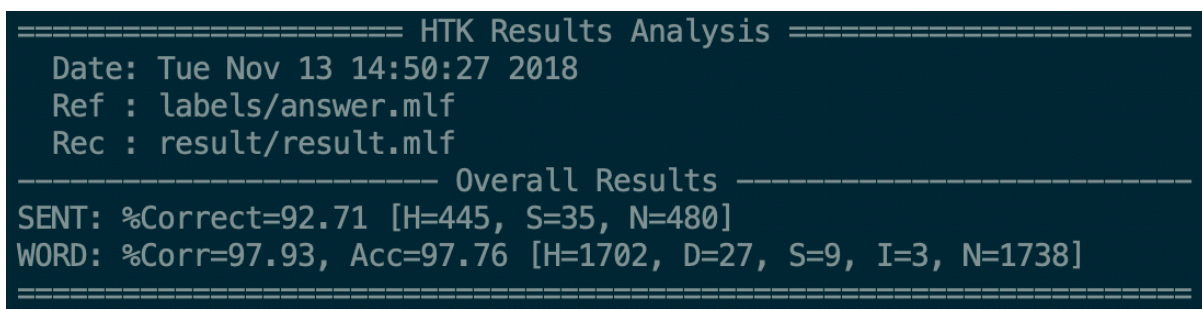
And run the given default scripts, an accuracy of **74.34%** is obtained:



```
===== HTK Results Analysis =====
Date: Tue Nov 13 11:05:25 2018
Ref : labels/answer.mlf
Rec : result/result.mlf
----- Overall Results -----
SENT: %Correct=38.54 [H=185, S=295, N=480]
WORD: %Corr=96.61, Acc=74.34 [H=1679, D=13, S=46, I=387, N=1738]
=====
```

Part 2 - Improve Accuracy

By adjusting the parameters in “lib/proto”, “lib/mix2_10.hed”, and “03_training.sh”, accuracy was improved significantly. An optimal accuracy of **97.76%** is obtained, the implementation details that achieves this performance is described in the next section.



```
===== HTK Results Analysis =====
Date: Tue Nov 13 14:50:27 2018
Ref : labels/answer.mlf
Rec : result/result.mlf
----- Overall Results -----
SENT: %Correct=92.71 [H=445, S=35, N=480]
WORD: %Corr=97.93, Acc=97.76 [H=1702, D=27, S=9, I=3, N=1738]
=====
```

Part 3 - Describing Training Process and Accuracy

Parameters that achieves the highest accuracy:

- Number of states: **15**
- Gaussian mixtures: **8**
- Iterations: **16 and 32**

Implementation Details:

- lib/proto

1) Number of states is modified to:

```
<NumStates> 15
```

2) Add <state, mean, variance> until 14:

```
<State> 14
<Mean> 39
0.0 0.0 0.0 0.0 0.
0.0 0.0 0.0
<Variance> 39
1.0 1.0 1.0 1.0 1.
1.0 1.0 1.0
```

3) TransP is modified to:

```
<TransP> 15
```

4) Transition matrix is modified so that
the probability of jumping to the next
state and the original state are both 0.5:

```
0.0 1.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.5 0.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.5 0.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.5 0.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.5 0.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.5 0.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.5 0.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.5 0.5 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.5 0.5 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.5 0.5 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.5 0.5 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.5 0.5 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.5 0.5 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.5 0.5
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
```

- lib/mix2_10.hed

1) Every *.state[2-9].mix is modified to:

```
.state[2-14].mix
```

2) Number of Gaussian is modified to:

```
MU 8
```

- 03_training.sh

1) The first two for loops are modified to:

```
for i in $(seq 0 15) ;
```

2) The last for loop is modified to:

```
for i in $(seq 0 31) ;
```

Training Process:

I wrote an additional shell script to help me run the whole training and testing pipeline, after the above modification, run these commands and the result shown in Part 2 can be reproduced:

```
run.sh
1  #!/bin/bash
2  bash 00_clean_all.sh
3  bash 01_run_HCopy.sh
4  bash 02_run_HCompV.sh
5  bash 03_training.sh
6  bash 04_testing.sh
7  echo "Complete."
```

Experiments:

Below I will demonstrate some interesting discoveries I found during my attempts to achieve a higher accuracy. We can briefly analyze how the above change of parameters affects the performance by changing the parameters one at a time, and compare its performance with the baseline model (The one in Part 1):

- **The effect of number of states:** set the values of Gaussian mixtures and iterations to the default baseline values, and increase the number of states. Number of states is tripled in this experiment (5 → 15), accuracy is increased from **74.34%** to **95.91%**.

```
===== HTK Results Analysis =====
Date: Tue Nov 13 14:24:44 2018
Ref : labels/answer.mlf
Rec : result/result.mlf
----- Overall Results -----
SENT: %Correct=87.50 [H=420, S=60, N=480]
WORD: %Corr=96.26, Acc=95.91 [H=1673, D=41, S=24, I=6, N=1738]
=====
```

• **The effect of Gaussian mixtures:** Set the values of number of states and iterations to the default baseline values, and increase the number of Gaussian mixtures. Number of Gaussian mixtures is doubled in this experiment ($2 \rightarrow 4$), accuracy is increased from **74.34% to 76.47%.**

```
===== HTK Results Analysis =====
Date: Tue Nov 13 14:05:24 2018
Ref : labels/answer.mlf
Rec : result/result.mlf
----- Overall Results -----
SENT: %Correct=43.75 [H=210, S=270, N=480]
WORD: %Corr=96.72, Acc=76.47 [H=1681, D=12, S=45, I=352, N=1738]
=====
```

• **The effect of Iteration:** Set the values of number of states and Gaussian mixtures to the default baseline values, and increase the number of iterations. Number of iteration is doubled in this experiment ($3 \rightarrow 6$ and $6 \rightarrow 12$), accuracy is increased from **74.34% to 76.29%.**

```
===== HTK Results Analysis =====
Date: Tue Nov 13 13:54:46 2018
Ref : labels/answer.mlf
Rec : result/result.mlf
----- Overall Results -----
SENT: %Correct=42.92 [H=206, S=274, N=480]
WORD: %Corr=96.84, Acc=76.29 [H=1683, D=11, S=44, I=357, N=1738]
=====
```

We can easily observe that the **increment in the number of states, contributes the most to the boost in performance.** Increasing the number of Gaussian mixtures and the number of iteration also increase the performance by a small margin. Hence I use a mixture of the above adjustments, and obtain the best result shown in Part 2.