Data Mining and Machine Learning

Speech Recognition using HTK

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Objectives

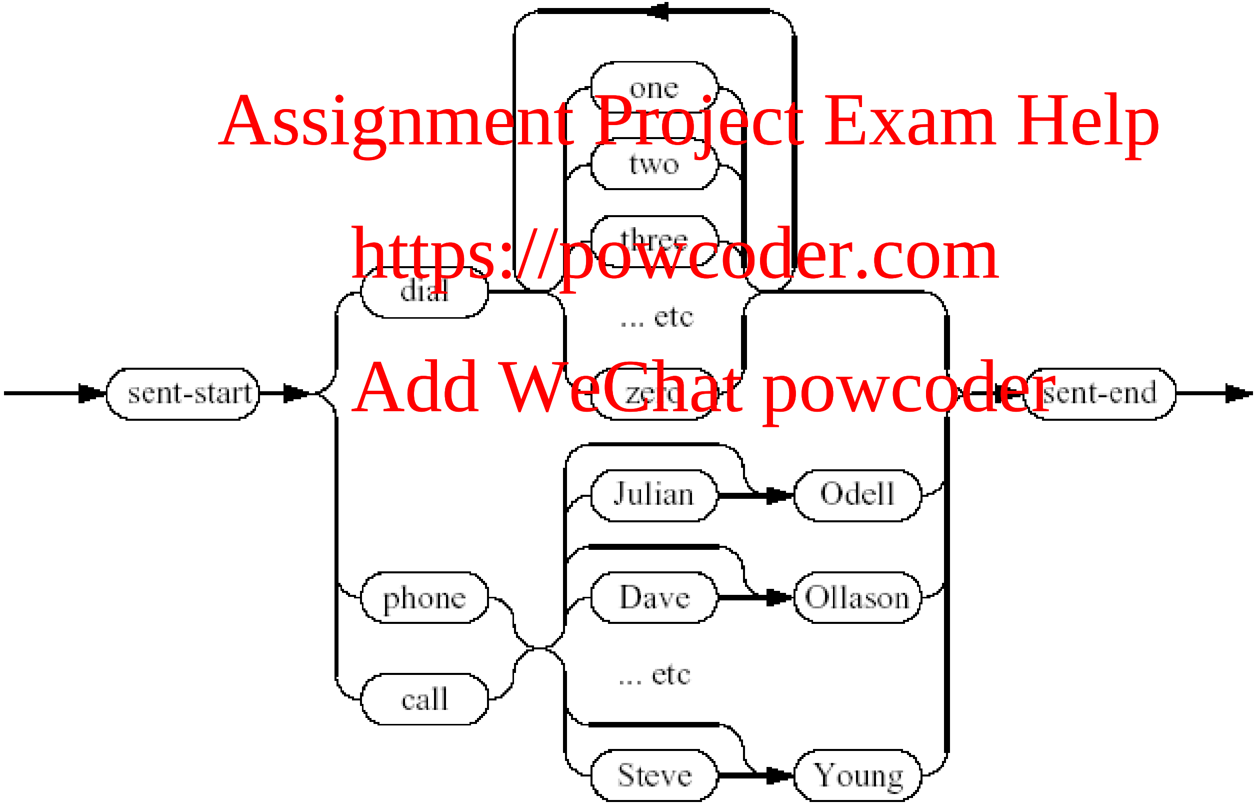
- Building an ASR system using Hidden Markov Model Toolkit (HTK)
  - Feature Representation
  - Training
  - Recognition (Testing)
- Introduction to Perl

ASR system using HTK

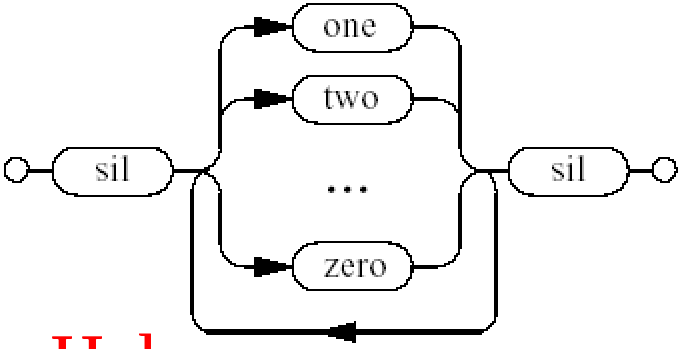
- Hidden Markov Model toolkit (HTK) – available for free download at http://htk.eng.cam.ac.uk/
  - Set of tools – located in c:\HTK\HTK3.2bin
    - exe-files
    - manual for the toolkit HTKManual
  - Tools likely to be used: HBuild, HCompV, HERest, HInit, HList, HCopy, HRest, HLEd, HVite, HResult
  - Each tool called separately – passed input parameters, e.g., configuration files, list of files to be processed, etc.
- Chapter 3 in the HTK Manual (but phoneme-level)
- Connected digit ASR system

Task grammar

- Task grammar for voice dialing



Task grammar



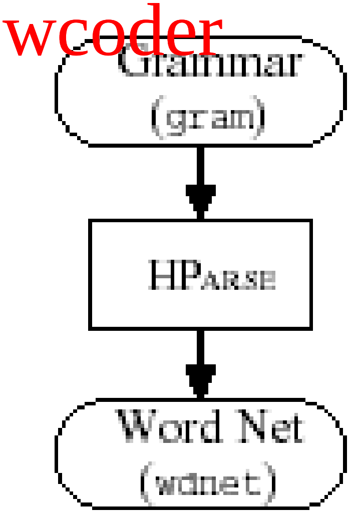
- Task – connected digits recognition
  - Word-list file contains:

    one two … nine oh zero sil sp

- Create a text-file called 'gram' containing (p.160 in HTK)

```
(
sil < one | two | three | four | five |
six | seven | eight | nine | zero > sil
)
```

- HParse.exe gram wdnet



```
VERSION=1.0
N=9   L=22
I=0    W=sil
I=1   W=one
I=2   W=two
I=3    W=three
I=4   W=sil
I=5   W=!NULL
I=6   W=!NULL
J=0     S=0    E=7
J=1     S=1    E=0
J=2     S=1    E=7
etc
```

Dictionary

- Dictionary for phoneme-level HMMs
  - Contains a list of words required in the task + their pronunciation, i.e., phoneme-level transcription
  - Example: five /f/ /ay/ /v/
  - Create using HDMan tool
- Dictionary for word-level HMMs
  - Pronunciation is the copy of the list of words
  - Example:

one	one
two	two

Data preparation

- Record data or use database provided
  - Training data – estimation of the parameters of the ASR system
  - Testing data – evaluation of the performance

- Label files – transcription of the spoken utterance – collected into Master Label File (.mlf)

  - Phoneme-level
  - Word-level

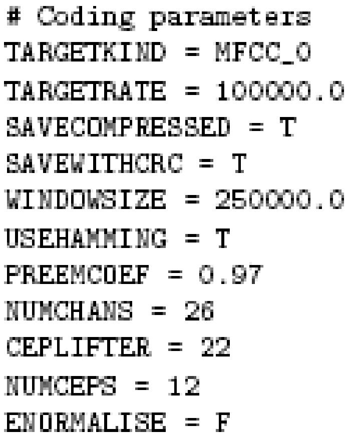
- Example: label_trainClean_noSP.mlf contains:

```
#!MLF!#
"*/FAC_13A.lab“
Sil
One
Three
Sil
.
etc
```

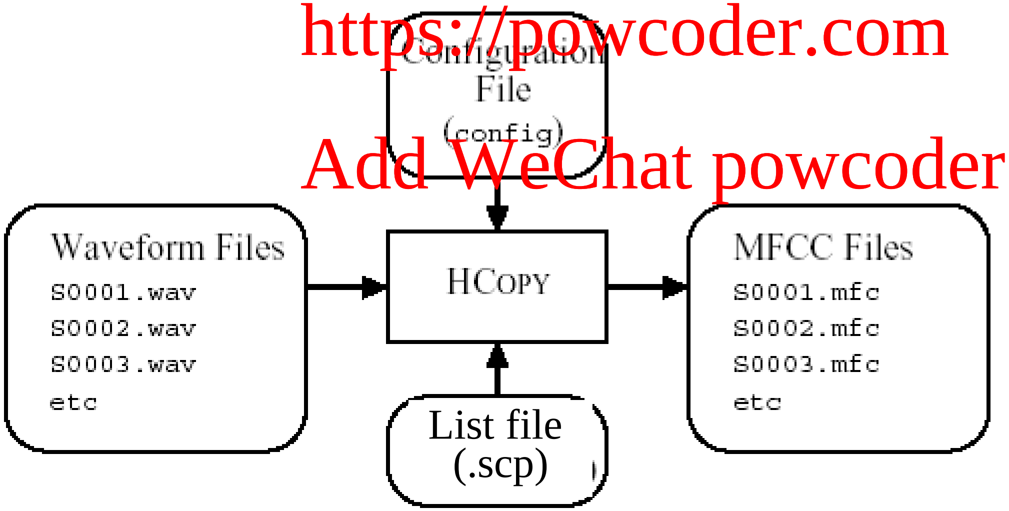
- s

Feature extraction

- Extraction of speech acoustic features, e.g., MFCC, logFBE, LPC etc
- Use HCopy tool (Ch5 in HTK, p. 55-75)



```
# Coding parameters
TARGETKIND = MFCC_0
TARGETRATE = 100000.0
SAVECOMPRESSED = T
SAVEWITHCRC = T
WINDOWSIZE = 250000.0
USEHAMMING = T
PREEMCOEF = 0.97
NUMCHANS = 26
CEPLIFTER = 22
NUMCEPS = 12
ENORMALISE = F
```



Creating word-level HMMs

- Training procedure
  - A set of single-Gaussian word-level HMMs
  - Start with a set of identical HMMs – means and variances are identical for all word models
  - Then perform several training iterations
  - Add short-pause (sp)
  - Loop: increase number of mixtures & perform several training iterations
  - Perform several final training iterations

Prototype HMM

- Define a prototype model – defines the model topology
  - number of states, covariance matrix type, feature type, feature dimension, number of streams
- Example: 8 state left-to-right HMM, no skips, diagonal covariance matrix, 1 stream, 39 dim feature vector

  Write a text-file containing:

```
<BeginHMM>
 <NumStates> 10 <VecSize> 39 <MFCC> <nullD> <diagC>
 <StreamInfo> 1 39
 <State> 2 <NumMixes> 1
  <Stream> 1
  <Mixture> 1 1.0
    <Mean> 39
      0.0 0.0 0.0 …
    <Variance> 39
      1.0 1.0 1.0 1.0 …
 <State> 3 <NumMixes> 1
  <Stream> 1
  <Mixture> 1 1.0
    <Mean> 39
      0.0 0.0 0.0 …
    <Variance> 39
      1.0 1.0 1.0 1.0 …
 <State> 4 <NumMixes> 1
  <Stream> 1
  <Mixture> 1 1.0
    <Mean> 39
…
```

Training – flat start (HCompV)

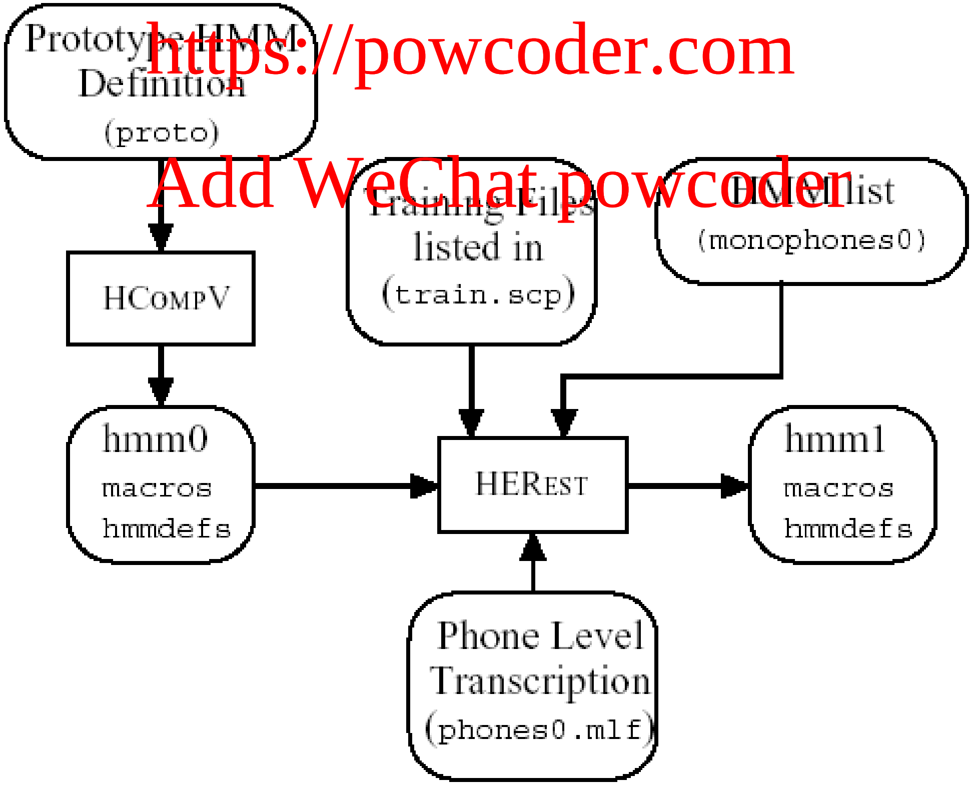
- Tool HCompV
  - compute the global mean and variance over the entire training data
  - set parameters of all of the Gaussians in a given HMM to these values
- HCompV.exe -C config -o hmmdef -f 0.01 -m -S listTrain.scp -M hmm0 proto
  - creates a new version of the ‘proto’ with name ‘hmmdef’ in the directory ‘hmm0’
  - the zero means and unit variances replaced by the global speech means and variances
  - options: ‘-f’ – variance floor; ‘-o’ – output filename; ‘-S’ – file list

Training – creating initial HMMs

- Using ‘hmmdef’, construct HMM for all vocabulary units (digits, phonemes)
  - manually copying the ‘hmmdef’ and relabeling it for each required digit (including ‘sil’)
  - automatically – write a small program in Perl or C (etc)
    - provided exe-files: macros.exe, models_1mixsil.exe

Training – HMM estimation (HERest)

- Tool HERest – estimation of the HMM parameters using Baum-Welch algorithm
- HERest -D -C $CONFIG -I $LABELS -t 250.0 150.0 1000.0 -S $LIST_FILE -H $HMM_DIR/hmm1/macros -H $HMM_DIR/hmm1/models -M $HMM_DIR/hmm2 $WORD_LIST


Prototype HMM Definition (proto)
HCompV
hmm0 macros hmmdefs
Training Files listed in (train.scp)
HMM list (monophones0)
HERest
hmm1 macros hmmdefs
Phone Level Transcription (phones0.mlf)

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Training – HMM estimation (HERest)

- Perform several estimation iterations using the HERest
- Then generate ‘short-pause’ (sp) model

  - Copy the central state of the ‘sil’ model

  - The ‘sp’ model is tied with the middle state of the ‘sil’ model (HHEd tool used here)

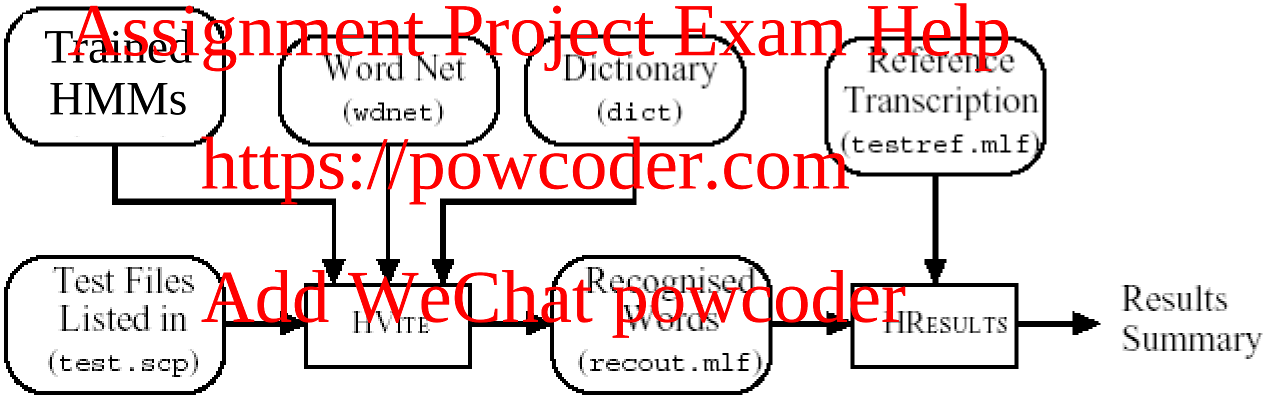
- Add the ‘sp’ in the last line of the WORD_LIST

Training – mixture increase (HHEd)

- Tool HHEd – various functions, including, increasing the number of mixtures
- Uses .hed file as input to define the function to be performed
- HHEd -H $HMM_DIR/hmm8/macros -H $HMM_DIR/hmm8/models -M $HMM_DIR/hmm9 $ED_CMDFILE2 $WORD_LISTSP
  - the file macros should contain the variance floor macro vFloors generated earlier

Recognition – HVite

- Tool HVite – performs recognition of an unknown utterance by using the Viterbi algorithm


Trained HMMs
Word Net (wdnet)
Dictionary (dict)
Reference Transcription (testref.mlf)
Test Files Listed in (test.scp)
HVITE
Recognised Words (recout.mlf)
HRESULTS
Results Summary

```
#!MLF!#
"c:/Experiments/SpeechRecogHTK/dataAurora2/spec_ff3dct2a1/TESTA/CLEAN1/FAK_1B.rec“
0 2100000 sil -1527.106689
2100000 9100000 one -6118.945313
9100000 9200000 sp -74.889305
9200000 10900000 sil -1286.454468
.
"c:/Experiments/SpeechRecogHTK/dataAurora2/spec_ff3dct2a1/TESTA/CLEAN1/FAK_2B.rec“
etc
```

Recognition – HResults

- Compares the recout.mlf with the reference .mlf file – gives the recognition performance
- SENT: 197 of the 200 test utterances (98.50%) were correctly recognised
- WORD:
  - Indicates that of the 855 words (N) in total, 853 (99.77%) were recognised correctly
  - There was 1 deletion error (D), 1 substitution error (S) and 1 insertion error (I)
  - The accuracy figure (Acc) of 99.65% is lower than the percentage correct (Cor) because it takes account of the insertion errors which the latter ignores

```
==================== HTK Results Analysis =============
Date: Sun Oct 22 16:14:45 1995
Ref : testrefs.mlf
Rec : recout.mlf
------------------------ Overall Results -----------------
SENT: %Correct=98.50 [H=197, S=3, N=200]
WORD: %Corr=99.77, Acc=99.65 [H=853, D=1, S=1, I=1, N=855]
=======================================================
```

Introduction to Perl language

- Perl
  - programming language – text processing, e.g., files, strings
  - available on any operating system

- Creating and running a Perl program
  - text file
  - Perl interpreter reads line by line and executes
  - run in the command prompt window

```
> perl myprog.pl
```

Perl program

- Similar to C syntax
  - statements terminated by ;
  - comments begin with #
  - logical operators &&, ||, ! as in C

- Variables
  - no need to pre-declare – variables are global

```
$x = 2;                          # variable ‘x’ will hold value 2
$greet = “hello”;      # variable ‘greet’ will hold string
   ‘hello’
```

Perl program – Arrays

- Arrays

```
@array = (1, 2, “hello”);                 # a 3 element array
$x=1;
$y=2;
@nums = ($x+$y, $x-$y);                   # variable ‘nums’ holds (3, -1)
$array[0] = $array[0] + $array[1];        # array[0] now holds 3
$len = @array;          # variable ‘len’ holds 3 (the length of @array)
```

Perl program – Conditions

```
if (expr) {
    stmt;
}
else {                          elseif (expr) {
    stmt;                           stmt;
}                               }


if ($x > 3) { $x = 3; }
```

Perl program – Loops 1

```
while (expr) {
    stmt;
}
for (init_expr; test_expr; incr_expr) {
    stmt;
}
for ($i=0; $i<100; $i++) {
    stmt;
}
```

Perl program – Loops 2

- Iterating over all elements of an array

```
foreach $var (@array) {
    stmt;           # $var pointer to the current element in
    @array
}
```

Perl program – External programs

- Running external programs
  - runs the HCopy.exe (from the HTK toolkit) with the given input parameters

```
system(“HCopy.exe –”);
```

Perl program – File operations, Print

- File handles to filenames as in C

```
open(F1, “filename”);        # opens ‘filename’ for reading
open(F2, “>filename”);       # opens ‘filename’ for writing
open(F3, “>>filename”);      # opens ‘filename’ for appending
close(F1);
```

- Print output

```
print “Woo Hoo\n”            # prints a string to stdout
```

Perl program – Print output

- Example print output to a file

```
$fname = “file.txt”;

open(FILE, $fname) || die “Could not open $fname \n”;

print $FILE “So, that’s the END of the Perl intro.\n”;
```

- Perl Introduction based on

  http://cslibrary.stanford.edu/108/