

Speech recognition and synthesis

1 TTS and ASR: A synthesis

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Introduction

Classical

TTS: Text \Rightarrow Accents \Rightarrow Phonemes \Rightarrow Prosody \Rightarrow Sound

ASR: Sound \Rightarrow MFCC \Rightarrow HMM \Rightarrow Language Model \Rightarrow Text

TTS and ASR: Recognition by synthesis, or synthesize by recognition

- Both synthesis and recognition work by comparing speech to a stored model
- Recognition works by synthesizing speech
- Synthesis works by reproducing stored speech
- Can a synthesizer really be used to recognize?
- Can a recognizer really be used to synthesize?



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New and Improved

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Introduction: The computational challenge

There is no data like more data, but how to use it?

- Computers become exponentially faster over time
- Speech corpora become exponentially larger over time
- Current HMM speech recognition only marginally better than 10 years ago
- Current synthesis idem
- How can computer speed and corpus size be harnessed?



ASR: Standard HMM

Problems in HMM

- Conditional Independent and Identical Distribution (IID)
- Speech can be described as a sequence of discrete units (phonemes)
- Strip all non-verbal (indexial) information
- Cannot use indexial information (eg, coarticulation)
- Adapt to rate, hypo/hyperarticulation
- \Rightarrow standard HMM models cannot store enough information



ASR: Structure-based approach

Model the parameters of speech production

- Establish mathematical models for stochastic trajectories or segments
- Eg, piecewise polynomials, linear dynamic systems, nonlinear dynamic systems
- Model speech dynamics i.o. acoustics (hypo/hyperarticulation, rate)
- Hidden dynamic models look at articulation
⇒ Articulatory Synthesis
- Combine hidden dynamic vectors with observed acoustic feature vectors
- ⇒ Explicitly model and train other factors



ASR: Template based recognition

Speech contains two types of information

- Verbal information
- Indexial (non-verbal) information
- Words versus Form
- HMM handles the words, but not the Form
- Form includes F_0 and speaking rate
- Form also includes speaker specific information
- Fine phonetic detail can influence recognition
- Eg, 1st syllable of *ham* versus *hamster*
- ASR model needed that can handle indexial information



ASR: Speech recognition by unit synthesis

HMM derives abstract model from examples

- Don't abstract, use examples directly
- Store speech of many speakers
- For each speaker, store lots of speech (words)
- Store different styles of speech, and label them
- \Rightarrow Template-, exemplar-, instance- based ASR



ASR: Template based

Store as much speech as possible

- Add transcriptions and labels
- Store all indexial and textual information
- What was said, by whom, and how
- Words are stored as many example feature vectors “trajectories”
- Preserving as many details as possible
- Incoming signal is compared to sequences of trajectories



ASR: Cookbook

Train knowledge sources of a template based recognizer

- 1 Segment and transcribe the training database.
The result is a segmentation file with phoneme transcriptions and phonetic boundary timings
- 2 Merge consecutive segments at will to produce supra-phonemic templates
- 3 Determine meta-information for each segment
- 4 Determine suitable transition costs to each pair of possible meta-tags
- 5 Assign suitable acoustic scaling matrices for each frame in the database
- 6 Calculate an indexing structure for fast k-nearest neighbours selection
- 7 Compute weights to combine the different knowledge sources

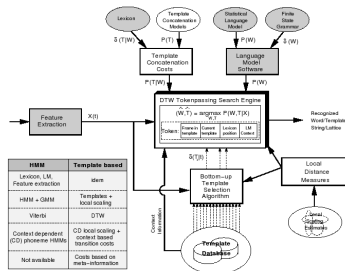
ASR: Template definition

A template is the representation of an actual segment of speech. It consists of

- a sequence of consecutive acoustic feature vectors (or frames)
- a transcription of the sounds or words it represents (typically one or more phonetic symbols)
- knowledge of neighbouring templates (a template number if no templates overlap)
- a tag with meta-information



ASR: Architectural overview



Correspondence between HMM and Template based ASR

- Distances are calculated to template cluster centroids
- Clustered acoustic vectors are a kind of degenerated HMM
- Train the costs of going from one template (fragment) to another

[De Wachter et al.(2007)De Wachter, Matton, Demuyne, Wambacq, Cools, and Van Compernelle]

HMM based TTS: The challenge of TTS

There is never enough speech

- Every utterance and situation are different
- “Expressive” speech needs even more different utterances
- Recording a new speaker for every new application is not acceptable
- Speaker time becomes limiting factor
- ... and it is never enough



HMM based TTS: Speech synthesis by HMM recognition

Unit selection is inflexible

- Speech units cannot be adapted to needs
- Abstract from specific speaker and example
- Model speech stochastically and select most likely utterance



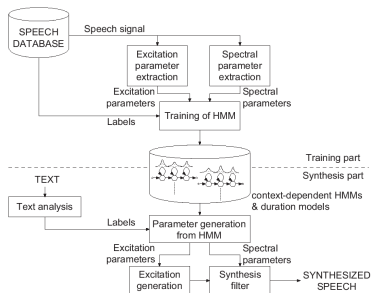
HMM based TTS: HMM models

Add a lot of flexibility

- HMM states can average over a cluster of contexts
- Store the dynamics of spectral change etc.
- HMM models for a new speaker can be learned
- New speaker or language *only* needs the difference
- The difference can be determined on just a little speech
- HMM TTS is *adaptable*
- (and you can indeed synthesize *MFCC* vectors)



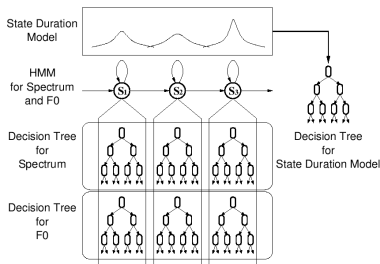
HMM based TTS



Store abstract, generalized units

- HMM states summarize spectrum words
- Model intonation (excitation) separately
- Label HMMs with contextual information

HMM based TTS:



Decision-tree based context clustering

- Many contextual factors (e.g., phone identity factors, stress-related factors, locational factors)
- Context-dependent HMMs
- Not enough speech and time \Rightarrow Cluster

HMM based TTS:

Table 1. Binary file size of HTS run-time engine.

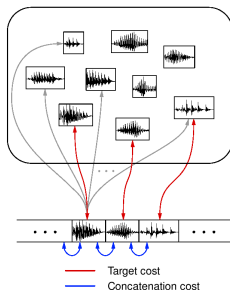
module		size
decision tree	spectrum	102 kbyte
	F_0	156 kbyte
	duration	116 kbyte
distribution	spectrum	457 kbyte
	F_0	81 kbyte
	duration	39 kbyte
converter		3 kbyte
synthesizer		34 kbyte
total		988 kbyte

Reduce footprint

- Small enough for PDAs
- Ten times Real-Time (on P4)
- HTS example using Alan's voice

[Tokuda et al.(2002)Tokuda, Zen, and Black]

HMM based TTS:

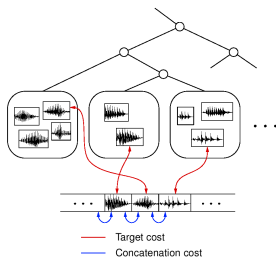


Classical Unit Selection scheme

- Concatenate using Target and Concatenation costs
- Use whole speech database
- Concatenate in real time

[Tokuda et al.(2002)Tokuda, Zen, and Black]

HMM based TTS:



HTS scheme

- Cluster all units on context in advance
- But use only statistics of cluster, not original templates
- Concatenation cost corresponds to dynamic feature parameter

[Tokuda et al.(2002)Tokuda, Zen, and Black]

HMM based TTS:

Table 2. Relation between unit selection and generation approaches.

Unit selection	HTS
Clustering (possible use of HMM)	Clustering (use of HMM)
Multi-template	Statistics
Single tree	Multiple tree (Spectrum, F0, duration)
Advantage: • High quality at waveform level	Disadvantage: • Vocoded speech (buzzy)
Disadvantage: • Discontinuity • Hit or miss	Advantage: • Smooth • Stable
• Large run-time data	• Small run-time data
• Fixed voice	• Various voices

Comparison

- Unit selection often very good, sometimes really bad
- HMM often bad (vocoder)
- HMM is much smaller and adaptable (retraining)

[Tokuda et al.(2002)Tokuda, Zen, and Black]

Further Reading I



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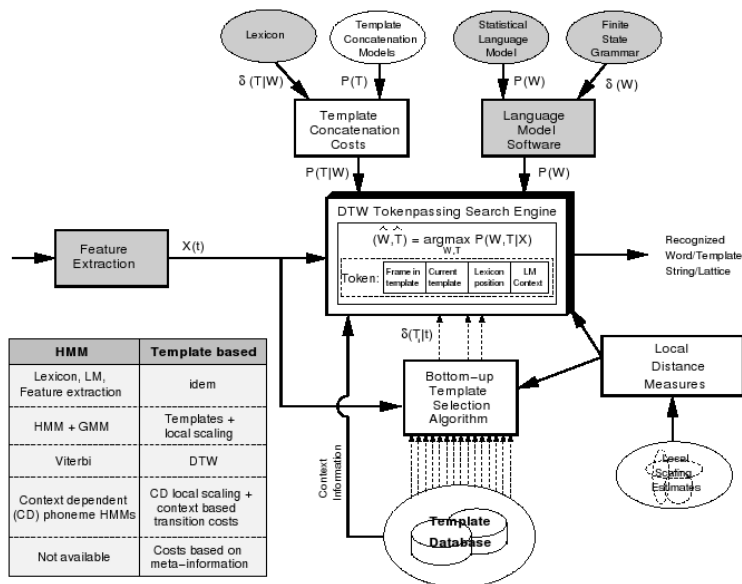
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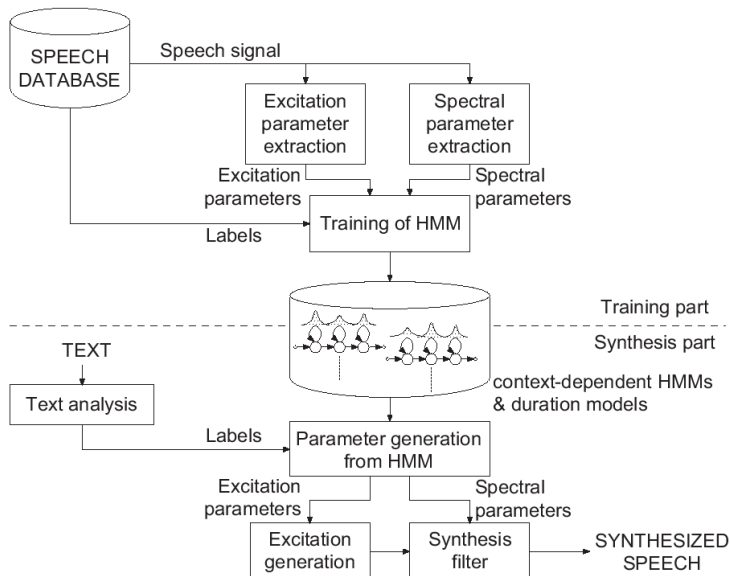
URL <http://www.fon.hum.uva.nl/rob/Publications/ArtikelSIGdial2005.pdf>.



Architectural overview template based ASR



Architectural overview HMM based synthesis



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