Text to Speech: Overview

Summer Course: Low Resource Languages

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Overview

- Speech Synthesis History: From knowledge-based to data driven
  - Formant to Diphone
  - Diphone to Unit Selection
  - Unit Selection to Statistical Parametric
- Optimizing the Problem
  - The right measures, the right algorithm
  - The right databases, the right things to synthesize
- Some Hard Problems
- Evaluation

Physical Models

- Blowing air through tubes…
  - von Kemplen’s synthesizer 1791

- Synthesis by physical models
  - Homer Dudley’s Voder. 1939

More Computation – More Data

- Formant synthesis (60s-80s)
  - Waveform construction from components
- Diphone synthesis (80s-90s)
  - Waveform by concatenation of small number of instances of speech
- Unit selection (90s-00s)
  - Waveform by concatenation of very large number of instances of speech
- Statistical Parametric Synthesis (00s-..)
  - Waveform construction from parametric models

Waveform Generation

- Formant synthesis
- Random word/phrase concatenation
- Phone concatenation
- Diphone concatenation
- Sub-word unit selection
- Cluster based unit selection
- Statistical Parametric Synthesis

Building a Research Field

- Tools
  - Allow others to easily join the field
- Common Data Sets
  - Be able to concentrate on techniques
  - Have common comparisons
- Evaluation
  - Realistically compare techniques
- Have Users
  - Some one has to care about your results
- Don’t become stifled
  - Ensure there are new tasks and directions

Festival Speech Synthesis System

http://festvox.org/festival
General system for multi-lingual TTS
C/C++ code with Scheme scripting language
General replaceable modules
- lexicons, LTS, duration, intonation, phrasing, POS tagging tokenizing, diphone/unit selection

General Tools
- intonation analysis (F0, Tilt), signal processing CART building, n-grams, SCFG, WFST, OLS

No fixed theories
New languages without new C++ code
Multiplatform (Unix, Windows, OSX)
Full sources in distribution
Free Software

CMU FestVox Project

http://festvox.org

“I want it to speak like me!”

-Festival is an engine, how do you make voices

- Building Synthetic Voices
  - Tools, scripts, documentation
  - Discussion and examples for building voices
  - Example voice databases
  - Step by Step walkthroughs of processes

-Support for English and other languages

-Support for different waveform techniques:
  - diphone, unit selection, limit domain, HMM

- Other support: lexicon, prosody, text analysers

The CMU Flite project

http://cmuflite.org

"But I want it to run on my phone!"

- FLITE a fast, small, portable run-time synthesizer

  C based (no loaded files)

  Basic FestVox voices compiled into C/data

  Thread safe

  Suitable for embedded devices

  - Ipaq, Linux, WinCE, PalmOS, Symbian

  Scalable:

  - quality/size/speed trade offs
  - frequency based lexicon pruning

  Sizes:

  - 2.4Meg footprint (code+data+runtime RAM)
  - < 0.025 secs "time-to-speak"

Common Data Sets

- *Data drive techniques need data*
- *Diphone Databases*
  - *CSTR and CMU US English Diphone sets (kal and ked)*
- *CMU ARCTIC Databases*
  - *1200 phonetically balanced utterances (about 1 hour)*
  - *7 different speakers (2 male 2 female 3 accented)*
  - *EGG, phonetically labeled*
  - *Utterances chosen from out-of-copyright text*
  - *Easy to say*
  - *Freely distributable*
  - *Tools to build your own in your own language*

Blizzard Challenge

- Realistic evaluation
  - Under the same conditions
- Blizzard Challenge [Black and Tokuda]
  - Participants build voice from common dataset
  - Synthesis test sentences
  - Large set of listening experiments
  - Since 2005, now in 9^{th} year
  - 15-20 groups (Academia, Research Labs and Commercial Companies)

How to test synthesis

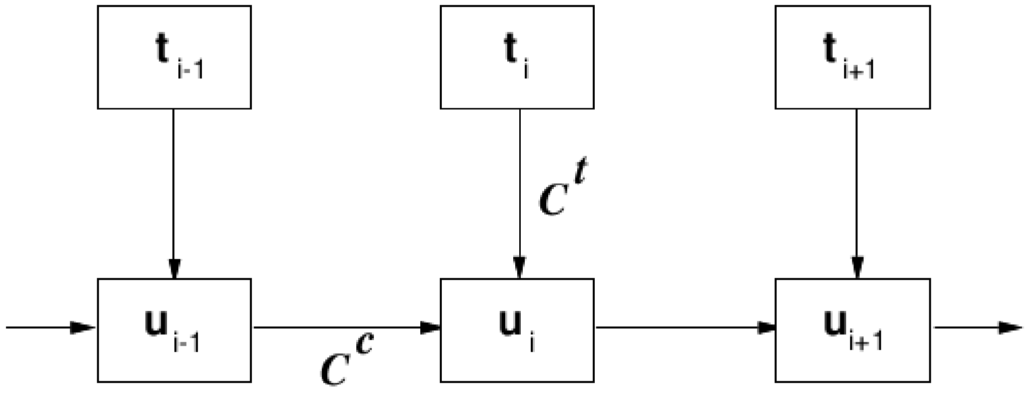
- *Blizzard tests:*
  - *Do you like it? (MOS scores)*
  - *Can you understand it?*
    - → *SUS sentence*
    - → *The unsure steaks overcame the zippy rudder*
- *Can't this be done automatically?*
  - *Not yet (at least not reliably enough)*
  - *But we now have lots of data for training techniques*
- *Why does it still sound like robot?*
  - *Need better (appropriate testing)*

Speech Synthesis Techniques

- Unit selection
- Statistical parameter synthesis
- Automated voice building
  - Database design
  - Language portability
- Voice conversion

Unit Selection

- Target cost and Join cost [Hunt and Black 96]
  - Target cost is distance from desired unit to actual unit in the databases
    - Based on phonetic, prosodic metrical context
  - Join cost is how well the selected units join



Clustering Units

- Cluster units [Donovan et al 96, Black et al 97]

$$Adist(U,V) = \begin{cases} \text{if } |V| > |U| & Adist(V,U) \\ \frac{WD*|U|}{|V|} * \sum_{i=1}^{|U|} \sum_{j=1}^{n} \frac{W_j.(abs(F_{ij}(U) - F_{(i*|V|/|U|)j}(V)))}{SD_j * n * |U|} \end{cases}$$

$|U|$ = number of frames in U

$F_{xy}(U)$ = parameter y of frame x of unit U

SD_j = standard deviation of parameter j

W_j = weight for parameter j

WD = duration penalty

Unit Selection Issues

- Cost metrics
  - Finding best weights, best techniques etc
- Database design
  - Best database coverage
- Automatic labeling accuracy
  - Finding errors/confidence
- Limited domain:
  - Target the databases to a particular application
  - Talking clocks
  - Targeted domain synthesis

Parametric Synthesis

- Probabilistic Models

$$argmax(P(O|W))$$

- Simplification

$$argmax(P(o_0|W), P(o_1|W), ..., P(o_n|W))$$

- Generative model
  - Predict acoustic frames from text

SPSS

- *ASR vs SPSS*
  - *Similar techniques but not the same*
- *Model training techniques*
  - *Alignment, and cluster features*
  - *MLLR (adaptation from multi-speaker models)*
- *Model improvement techniques*
  - *Minimum generation error*
  - *Label optimization*
- *Parameterization techniques*
  - *MFCC, LSP, STAIGHT, HSM*
  - *Excitation modeling techniques*

SPSS Goals

- Require optimal paramerization that
  - Is derivable from speech
  - Can generate high quality speech
  - Is predictable from text
- Candidates
  - Spectral, F0, excitation
  - Formants, nasality, aspiration
  - Articulatory features

Neural Synthesis

- *Neural Modeling*
  - *Text to spectrum: tachotron*
  - *Spectrum to waveform: wavenet*
- *Various toolkits (Falcon in Festvox)*
  - *Needs lots of data*
  - *And lots of training data*
  - *Can be better than unit selection*
  - *Can be more robust that SPSS*
  -

Building Synthetic Voices

The "standard" voice requires …

- A phone set
- Pronunciations:
  - Lexicon/letter-to-sound rules
- Phonetically and prosodically balanced corpus
  - Spoken by a good speaker
- Text analysis:
  - Number, symbol expansion, etc
- Prosodic modeling
  - Phrasing, intonation, duration etc
- Waveform generation
  - Diphones, unit selection, parametric synthesis
- Something else that is hard:
  - No vowels (Arabic), no word segmentation, number declensions

Designing a good corpus

- From a large set of text
  - Select “nice” utterances
  - 5 to 15 words, easy to say
  - All words in lexicon, no homographs
- Convert text to phoneme strings
  - Possibly with lexical stress, onset/coda, tone etc
- Select utterances that maximize di/triphone coverage
- Looking for around 1000 utterances
- Can seed initial data with “domain” data
- CMU ARCTIC databases
  - 7 x single speaker English DBS
  - 1200 phonetically balanced utterances

Hard Synthesis Problems

- Text Normalization
- Intonation modeling
  - Intonation evaluation
- Style modeling
  - Choosing the right style
  - Evaluating the result

Text Normalization

- *Finding the words*
  - *Tokenizing, homograph disambiguation etc*
  - *“$1.25” vs “$1.25 million” vs “$1.25 song”*
- *Very large number of rare events*
- *Formalized systems exist*
  - *Trained from data, optimized and out-of-date*
- *Long term updated hacks rule systems*
- *ML Challenge*
  - *Such a problem* **cannot** *be done by machine learning*

Intonation Modeling

- Accents, Phrases and F0
  - Lots of statistical models available
  - Lots of "objective" measures:
    - RMSE, Correlation
  - No good subjective measures
- Listening tests
  - Natural Intonation: good
  - Naïve intonation: bad
  - Various cute models for intonation: meh

Improving Understanding

- Take reading comprehension stories
  - For children’s reading tests, or TOEFL
- Synthesis with:
  - Natural Intonation
  - Naïve models
  - Various cute models
- Human listening tests
  - Answer questions about stories
  - Best system: Naïve models ☹

Style Modeling

- *Classic Emotion Modeling*
  - *Happy, sad, angry and neutral*
  - *But no one needs that*
- *Style Modeling*
  - *Polite, command, empathic*
- *Style usage*
  - *When can it be used?*
  - *How much should be used?*

Dialog with Style

- Record human-human dialog
  - Label dialog states:
    - → Implicit confirmation, corrections, discourse markers
- Build dialog state sensitive voice
  - Using dialog state in features
- Must be closely integrated into SDS
  - Timing, dialog state appropriate
- But how do you test it?

Conclusions

- Synthesis has improved
  - But there is still much to do
  - Isolated sentences are clear …
  - … But conversational speech still in the future
- Speech Systems must adapt
  - To their usage
  - And their funding conditions
- But we can always fall back on our talents