1 Automatic Text-To-Speech synthesis
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Copyright ©2005 R.J.J.H. van Son, GNU General Public License [FSF(1991)]
Uses of speech synthesis by computer

- Read aloud existing text, e.g., news, email, and stories
- Communicate volatile data as speech, e.g., weather reports, query results
- The computer part of interactive dialogs

The building block is a Text-to-Speech system that can handle standard text with a Speech Synthesis (XML) markup. The TTS system has to be able to generate acceptable speech from plain text, but can improve the quality using the markup tags.
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**Automatic Text-To-Speech synthesis**

**Introduction**

Computer Speech: Diphone synthesis

![Diphone synthesis](image)

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By dictionary and rules

Tokenize the text and look up the words in a pronunciation dictionary. If not found, use rules

- Dictionary entries: ("dictionary" nil (d ih1 k sh ax n eh1 r iy0))
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“allegation of incomprehensibility”

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Use a dictionary and include a morphological compound list with pronunciations. [Möbius(1998)]
Lexical stress and sentence accent: Prominence

In every utterance, one or more words are more prominent than others. They are:

- Accented, ie, carry a pitch movement
- Longer
- Louder
- Less reduced

Prominence is determined by

- Word type, function words are almost never prominent
- Word frequency, rare words are prominent more often
- New information is prominent, given is not
- Not too many prominent words in a row

There are rules for assigning prominence, but they need good POS tagging. Just accenting every content words works too.
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In every word, one or more syllables are more prominent than others. They are:

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Syllable stress is determined by

- The lexicon or language (lexical/fixed stress positions)
- Syllable weight, "heavy" syllable are stressed
- No stressed syllables in a row
- Informative syllables are stressed

 Mostly, you can get away with either the lexicon, or fixed positions. Syllable stress shifts in compound words. Morphological decomposition gives rules for these shifts
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Intonation covers utterances of a few words at a time (around 5-7). Breaking up sentences at acceptable places is difficult

- Use punctuation
- Guess boundaries on POS tags (HMM style)
- Do a partial syntactic parse and use phrases

In general, it is difficult to go beyond punctuation and some simple heuristics without syntactic parsing
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- Phoneme identity
- Surrounding phonemes
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- Syllable stress
- Syllable length and position (Onset, Coda)
- Word length
- Phrase/sentence boundary position
  
These factors are used to construct statistical models from annotated speech corpora. Golden standard is Correlation and Regression Trees (CART). But many other statistical methods are used.
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Intonation

With the durations known, the pitch contour can be calculated

- Speaker and style determine the pitch range
- Give each accent a pitch movement shape and size
- Assign each vowel its target $F_0$ value
- Interpolate the values into a valid contour
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Acoustic realization, PSOLA, MBROLA

Multi Band Excitation (Time Domain) Pitch Synchronous Overlap Add [MBROLA(2005)]

- Mark all pitch periods (blue pulses in *Praat*)
- Fixed periods for voiceless speech
- Window speech around each mark
- To lengthen/shorten a sound, reduplicate/delete periods
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Nextens

‘Nederlandse Extensie voor Tekst naar Spraak’ or ‘Dutch Extension for Text to Speech’ example

Nextens runs on top of Festival [Nextens(2003), Festvox(2005)]

- New Dutch voices in Festival
- Nintens GUI (io, commandline in Festival)
- Available for non-commercial use (not Open Source)
- Developed at the Radboud University and the University of Tilburg (Joop Kerkhof, Erwin Marsi, and others)
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Nextens: Annotation interface

Speech recognition and synthesis

Automatic Text-To-Speech synthesis

Introduction
Computer Speech
Text preprocessing
Grapheme to Phoneme conversion
Morphological decomposition
Lexical stress and sentence accent
Duration
Intonation
Acoustic realization, PSOLA, MBROLA

Nextens
Assignment
Bibliography

Nextens
File Font

ToDI F0 Parameters Command Line Log

Op een dag kwam de eekhoorn erachter dat het onverstandig was om niet verder te kunnen tellen dan tot vijf.

Hij ging naar de school aan de voet van de eik in het midden van het bos en vroeg aan de mus die daar onderwijzer was of hij hem tot tien kon leren tellen.

'IK zal mijn best doen,' zei de mus.

'Maar wat je vraagt is niet eenvoudig.'

Ik kan zelf tot zeventien tellen, maar vraag mij niet hoe lang ik daarvoor heb gestudeerd, want dat weet ik al niet meer.'

'IK heb er alles voor over,' zei de eekhoorn.

'De meeste dieren komen nooit verder dan twee.'

'Laten we maar beginnen.' zei de eekhoorn.

selection: u0001
Nextens: $F_0$ interface
Nextens: Parameters interface

- **Speak Rate**: 2 Default
- **Reference Frequency**: 85 Default
- **Range**: 1.89 Default
- **Register Width**: 1.60 Default
- **Down Step**: 0.94 Default

**selection: u0023**
Nextens: Commandline interface

(SayText "Dit is Nextens")

> (SayText "Dit is Nextens")
this came from the MBT tagger:
Pron(aanw,neut,zelfst) V(hulpofkopp,ott,3,ev) Adj(attr,stell,onver)

Dit -> Pron aanw,neut,zelfst
is -> V hulpofkopp,ott,3,ev
Nextens -> Adj attr,stell,onver
#<Utterance 0x40b375e8>
Assignment: Week 5 Using Nextens

See CD or Nextens web-site for information [Nextens(2003)]

- Install Nextens (see info)
- Start Nintens
- Under file menu, select ‘add sentence’
- Generate a sentence
- Inspect tabs, especially the ToDI tab
Assignment: Week 5 Using Nextens

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  - Generate a sentence
  - Inspect tabs, especially the ToDI tab
Assignment: Week 5 Using Nextens

See CD or Nextens web-site for information
[Nextens(2003)]

- Install Nextens (see info)
- Start Nintens
- Under file menu, select ‘add sentence’
- Generate a sentence
- Inspect tabs, especially the ToDI tab

Assignment: Week 5 Using Nextens

See CD or Nextens web-site for information
[Nextens(2003)]

- Install Nextens (see info)
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- Under file menu, select ‘add sentence’
- Generate a sentence
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Assignment: Week 5 Using Nextens

See CD or Nextens web-site for information
[Nextens(2003)]

- Install Nextens (see info)
- Start Nintens
- Under file menu, select ‘add sentence’
- Generate a sentence
- Inspect tabs, especially the ToDI tab
Further Reading

Christina L. Bennett.
Large Scale Evaluation of Corpus-based Synthesizers: Results and Lessons from the Blizzard Challenge 2005.
URL http://festvox.org/blizzard/bc2005/IS052023.PDF.

Alan W. Black and Kevin A. Lenzo.
Building Synthetic Voices.
Festvox, 2 January 2003a.
URL http://festvox.org/bsv/.
Published on the festvox website.

Alan W. Black and Kevin A. Lenzo.
Festvox.
Web, 2003b.
URL http://festvox.org/.
Festival speech synthesis.

Alan W. Black and Keiichi Tokuda.
The Blizzard Challenge 2005: Evaluating corpus-based speech synthesis on common datasets.
URL http://festvox.org/blizzard/bc2005/IS051946.PDF.

P. Boersma.
Praat, a system for doing phonetics by computer.
Further Reading II

P. Boersma and D. Weenink.
*Praat 4.2: doing phonetics by computer.*

Paulus Petrus Gerardus Boersma.
*Functional Phonology: Formalizing the Interactions between Articulatory and Perceptual Drives.*

Murtaza Bulut, Shrikanth S. Narayanan, and Ann K. Syrdal.
Expressive speech synthesis using a concatenative synthesizer.

Ronald A. Cole, Joseph Mariani, Hans Uszkoreit, Annie Zaenen, and Victor Zue, editors.
*Survey of the State of the Art in Human Language Technology.*
URL http://cslu.cse.ogi.edu/HLTsurvey/.

Festvox.
Festvox.
Web, 2005.
URL http://www.festvox.org/.

FSF.
*GNU General Public License.*
Further Reading III

**MBROLA.**
The MBROLA Project.
Web, 2005.
URL http://tcts.fpms.ac.be/synthesis/.
Synthesis.

**Bernd Möbius.**
word and syllable models for german text-to-speech synthesis.
URL http://www.slt.atr.co.jp/cocosda/jenolan/Proc/r06/r06.pdf.

**Gregor Möhler.**
Examples of Synthesized Speech.
Web, 2005.
URL http://www.ims.uni-stuttgart.de/~moehler/synthspeech/.
Good web-site with many examples.

**Nextens.**
NeXTeNS: Open Source Text-to-Speech for Dutch.

**Louis C.W. Pols, Jan P.H. van Santen, Masanobu Abe, Alan Black, David House, Mark Liberman, and Zhibiao Wu.**
Easy access via a TTS website to mono- and multilingual text-to-speech systems.
Further Reading IV

Project Gutenberg.
Project gutenberg free ebook library.
Web, 2005.
URL http://www.gutenberg.org/.

Richard Sproat.
ECE 598: Speech Synthesis.
Web.
URL http://catarina.ai.uiuc.edu/ECE598/Lectures/klattlpc.pdf.

SRL.
Synthesis of Speech.
Web.
URL http://wagstaff.asel.udel.edu/speech/tutorials/synthesis/.
Speech Research Lab, A.I. duPont hospital for children and University of Delaware.
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