Multimodal speech synthesis/ NGSLT - Speech Technology course

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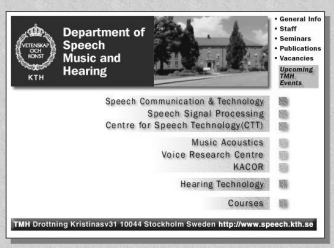
The work presented in this lecture is the result of many researchers' efforts at the Department of Speech, Music and Hearing

Reports and further information can be found on our home page www.speech.kth.se



Februari 1998

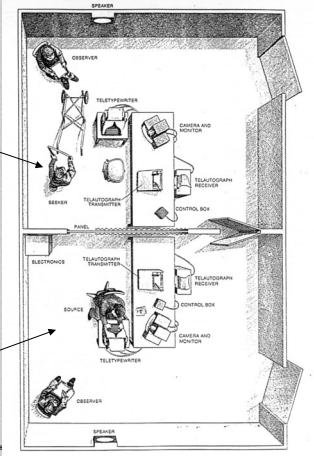
Why Speech Tech?

User

"Interactive Human Communication"

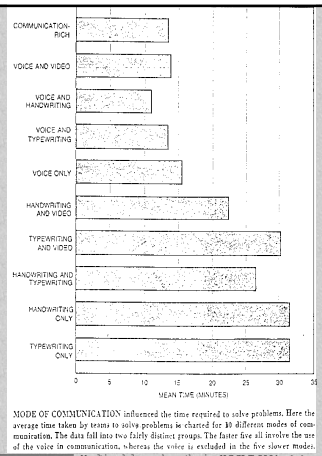
Chapanis Scientific American 1975!

"Computer"



More efficient and convenient!

Average time for solving divers problems using different combinations of means of communication



MODE OF COMMUNICATION influenced the time required to solve problems. Here the average time taken by teams to solve problems is charted for 10 different modes of communication. The data fall into two fairly distinct groups. The faster five all involve the use of the voice in communication, whereas the voice is excluded in the five slower modes.

Speech is fast and verbose

	COMMUNICATION-RICH	VOICE	HANDWRITING	TYPEWRITING EXPERIENCED TYPISTS	TYPEWRITING INEXPERIENCED TYPISTS
SOLUTION TIME IN MINUTES	29	33	53.3	66.2	69
NUMBER OF MESSAGES	230.4	163.8	15.9	27.2	31.5
NUMBER OF SENTENCES	372.6	275.9	24.9	45.8	44.1
TOTAL NUMBER OF WORDS	1,563.8	1,374.8	224.8	322.9	257.4
TOTAL NUMBER OF DIFFERENT WORDS	397.5	305.9	118.5	150.5	133.4
TYPE-TOKEN RATIO	.3	.3	.6	.5	.6
NUMBER OF WORDS PER MINUTE	190.3	171.2	17.3	18.1	10.2

EXPERIMENTAL RESULTS are enumerated for the solution of problems by various modes of communication. "Type-token ratio" is ratio of different words to total words. Problem solving by voice takes the least time but is wordier than the other modes are.

Speech technology is making money!

Classic example : AT&T and Lucent Technologies VRCP, "Voice Recognition Call Processing" sevice

- Selection of payment method
- Vocabulary only five words : collect, calling card, third number, person, operator
- More than 5 000 000 calls per day
- Earnings already (1999?) more than AT&T/Bell labs´ total investment in speech research

The first pen phone

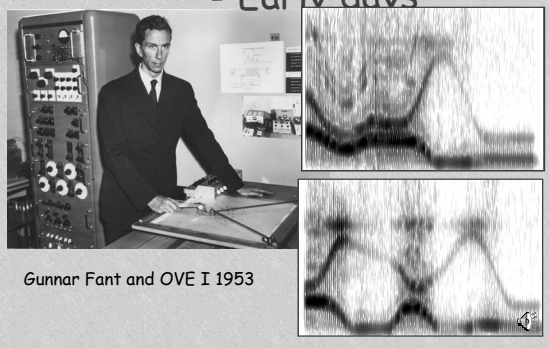
Why no commercial success?

Too small keys?

Too small display!?

1 april 1998

The KTH speech group - Early days



Gunnar Fant and OVE I 1953

OVE I, in the WaveSurfer tool

WaveSurfer

- Interface is based around WaveSurfer, a general purpose tool for speech and audio viewing, editing and labelling
- TTS and Talking Head functionality is added as plug-ins
- WaveSurfer (presently without TTS & TH) works on all common platforms and is freely available as open source
- Modules from Waves available – formants and F0 in present release – thanks to Microsoft and AT&T

http://www.speech.kth.se/wavesurfer

Ove II, 1958

1961

1962

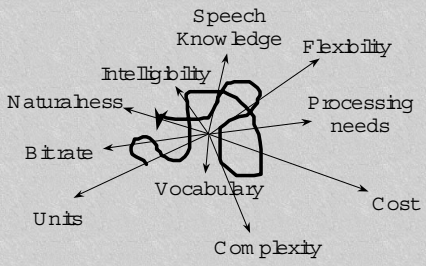
KTH/TTS history

- 1967, Digitally controlled OVE III
- 1974, Rule-based system RULSYS
  - transformation rules
- 1979, Mobile text-to-speech system
  - used by a non-vocal child
- 1982, Portable TTS (ICASSP, Paris)
  - Multilingual
  - MC 68000, NEC 7720
- 1983, Founding of Infovox Inc.

What do we mean by Speech synthesis?

- Recorded speech
  - Words or phrases (telephone banking)
  - Fixed vocabulary – maintenance problems…
- Concatenative speech synthesis
  - Diphones or larger units (unit selection)
    - LPC: source filter model (too simple?)
    - PSOLA/MBROLA/HNM – and rules for prosody
  - One speaker
- Parametric synthesis
  - Formant synthesis
  - Articulatory synthesis
  - flexible
  - But lower quality - today
- Mulitmodal synthesis

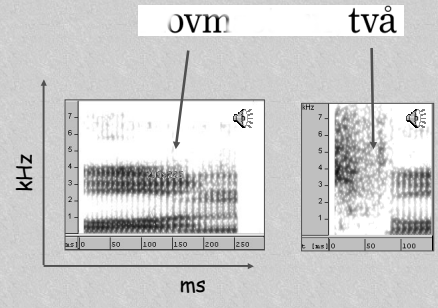
The synthesis space



TEXT vs SPEECH

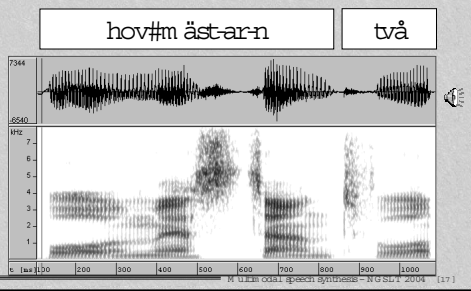
- Parallel vs. sequential
- permanent vs disappearing
- Text as transcription of speech?
- Example - WaveSurfer demo:
  - Palindrome
  - ”Var sak har två sidor”

Phonetics

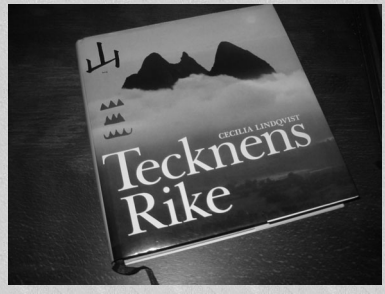


Phonology, Morphology

Hovmästarn, två

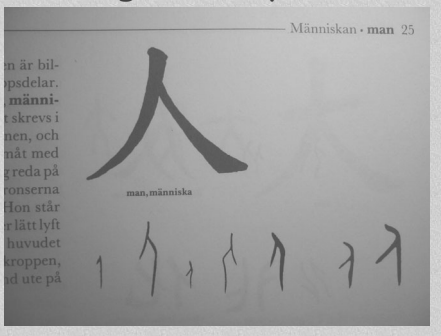


Non-phonetic writing

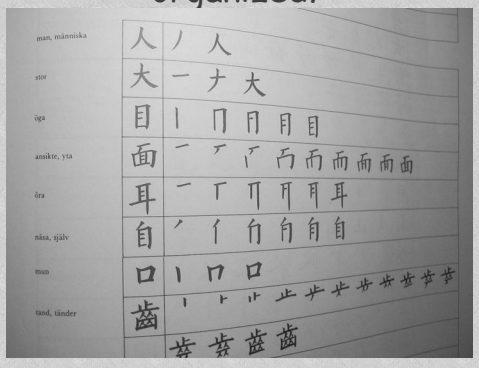


Signs vs. technology

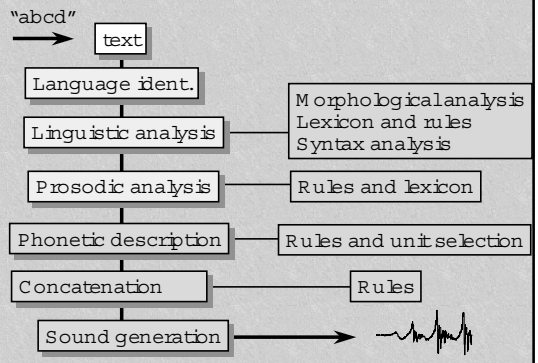
Is the sign what you think?



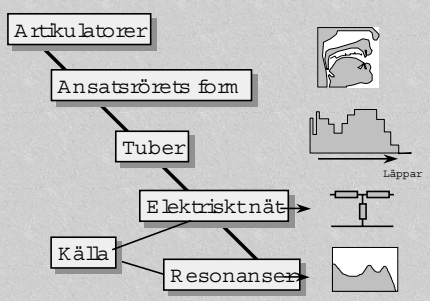
How is a Chinese lexicon organized?



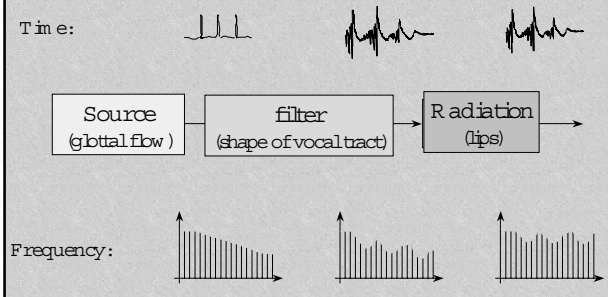
Text-to-speech (TTS)



Synthesis methods



Source filter theory



RULSYS Rules - Features

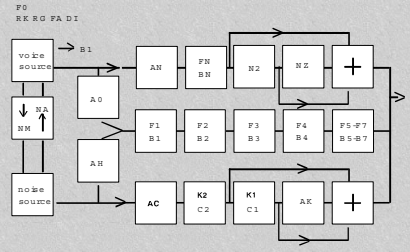
- Is IPA synthesiser possible?
- Based on generative phonology
- Language specific definitions
- Rules for contextual modifications
- Examples
- Interactive rule manipulations

(a) a → e / __ <cons> e #

(b)

morph		root	
graph	a		e
phon	<cons>	→	e

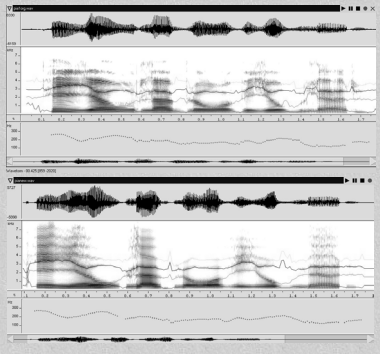
Glove



"Pia odlar blå violer"

Original

Synthesis



Carlson, R. Granström, B., and Karlsson, I. (1990): "Experiments with voice modeling in speech synthesis,"

Speaker characteristics

Speaker
dialect, sex, social, education, age

Situation
formality, style, interspeaker relation

Complex description
many dependent variables

Speaker characteristics

- TIDE/Vaess project (Voices, attitudes and emotions in synthetic speech
- "Voice fitting"
- Software, Glove synthesis
- 10 user controlled parameters
- Rule specified connection to synthesis parameters

Emotional/ubiquitous computing – do we want it?

Early BBC vision – the conversational toaster
Thanks to Mark Huckvale, UCL, for the video clip

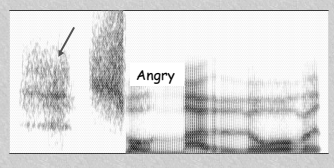
Emotions

natural synthesis

Neutral

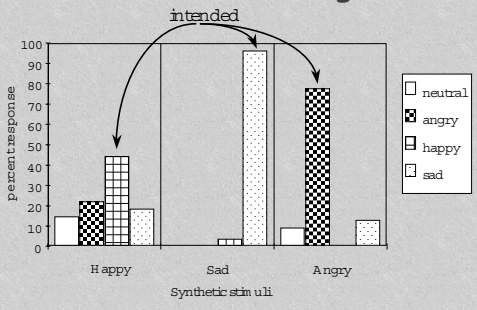
Happy

natural synthesis

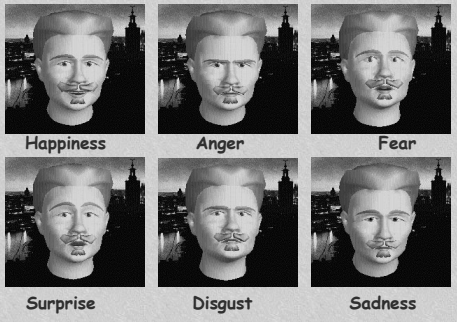


natural synthesis

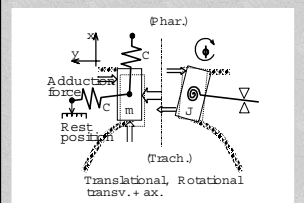
Result from listening test



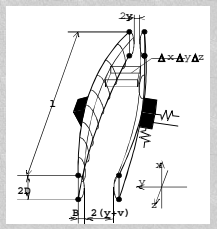
Emotions



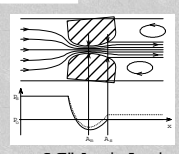
Källasimulering



Mekanisk modell



Geometrisk modell som två elastiska band



Luftflödet i glottis

Källasimuleringar med återsyntetisering

Samplingsintervall:	1 parameter
Stämbandsanatomi:	18 parameter, tex längd, vikt, dämpningsfaktor
Stämbandsartikulation:	7 parameter, tex restglapp, lungtryck
Högtrycksartikulation:	4 parameter, tex tonhöjd, ljudstyrka
Talrörsartikulation:	8 parameter, tex area, dämpningsfaktor

Exempel	originalyttrande
fördubblad stämbandsmassa	
förlängning av stämband 13->17 mm	
assymetriförändring 1.0->1.8	
assymetriförändring 1.0->2.0	
restgap 0.1->1.0 mm	

Predictable word accents

- Word accent and stress
  - anden (bird)
  - ånden (spirit)
  - ånk-pasta
  - ånk-pastej
  - ånk-pastejen
  - ånk-pastejs-mål-tid
- Name pronunciation
  - karl-åvik (karl-erik) + ånne-marie
  - Onomastica/EU
- Reduction
  - betòng-väg(g)s-konstruktion (C-C Elert)

Letter-to-sound vs. lexicon

Size vs. Precision

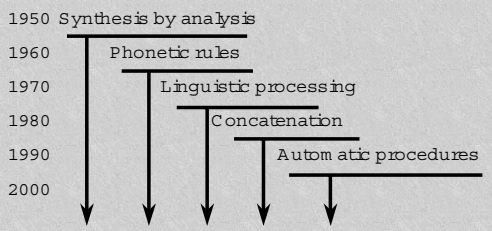
Maintenance - "half of the words are unique"

Name pronunciation (Onomastica Project)

Misspellings

Use rules, morphology, analogy... as fallback

Research trends in speech synthesis



Concatenative synthesis

- Already Peterson et al. (1958)
- Dixon and Maxey (1968)
- "Diadic Units", (Olive, 1977)
- "PSOLA", Charpentier and Stella (1986)
- Review, Möbius (2000)
- ICSLP 2002
  - Unit selection
  - Concatenation cost
  - Prosody

Concatenative synthesis Signal manipulations

- Prosodic modifications
  - Possibility to modify F0
  - Possibility to lengthen or shorten segments
- Spectral modifications
  - Interpolation of spectrum at joints
- Early technique - LPC

Speak&Spell - TexasInstrument Christmas 1978

PSOLA

- Pitch pulses moved in time to fit F0 contour
- Conceptually simple and computationally efficient
- Need for precise pitch pulse marking
- Could not handle spectral interpolation

Unit selection

- Large databases of recorded natural speech
- Minimal processing
- Annotation of database – what information is needed?
- Synthesis defaults to transcription and search problem
- Few cuts > maximally long units selected (but context and prosody must fit well)
- Target and concatenation costs

Synthesis methods

- Unit selection – minimal processing
  - chatr(ATR) weather (CSTR) good, less good
- Diphone synthesis
  - Svensk (Mbrola), Fransk (ICP) (CNET)
- Formant synthesis
  - Svensk (KTH), Fransk (KTH)

Unit selection - BrightSpeech

- Swedish
- Norwegian

Examples of Synthesized Speech
Universität Stuttgart
Institut für Maschinelle Sprachverarbeitung

[German] [English] [French] [Dutch] [Spanish] [Italian] [Portuguese] [Swedish] [Norwegian] [Finnish] [Estonian] [Icelandic] [Czech] [Russian] [Greek] [Croatian] [Romanian] [Japanese] [Chinese] [Korean] [Hebrew] [Arabic]

http://www.ims.unistuttgart.de/~moehler/synthspeech/examples.html
also e.g. http://www.naturalvoices.att.com/

To make it work today: Hybrid systems

e.g. Who has number nn....?
Key input – Synthesis mixed with recorded speech (Call +46 118 999)

Hybrid methods, cont.

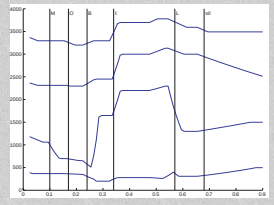
- *Rolf Carlson, Tor Sigvardson, Arvid Sjölander* (2002). Data-driven formant synthesis. *Proc of Fonetik 2002, TMH-QPSR*
  David Öhlin and Rolf Carlson Data-driven Formant Synthesis, Proc of Fonetik 2004
- *+ Four MSc theses (Sigvardson, Sjölander, Vinet, Öhlin)*
- *All available on* www.speech.kth.se

Aim

- Keeps the flexibility of the formant synthesis
- More natural sounding than rule-driven synthesis
- Speaker adaption

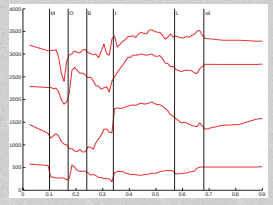
Rule-driven formant synthesis

- Parameters are generated by rule (RULSYS, Carlson et al)
- Formant values are generated by interpolating between target frequencies
- Parameters are fed to a synthesizer (GLOVE, Carlson et al)

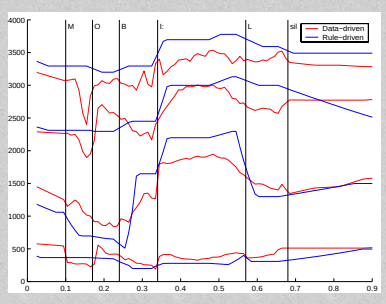


Data-driven formant synthesis

- Some parameters (namely, the first four formants) are replaced by data
- Same synthesizer



Synthesis comparison



Data-driven formant synthesis

- Formants are replaced through unit selection from a formant diphone library
- Formant trajectories are scaled and interpolated to fit the rule-generated durations

Cost function

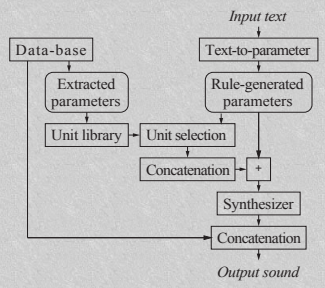
- Designed to promote probable formant candidates
- Penilizes:
  - Large bandwidths
  - Large frequency deviations (given the current phoneme)
  - Large frequency jumps (promotes smooth trajectories)

Voiceless consonants

- Replace the voiceless fricatives and plosives with recorded versions
- Voiceless fricatives in Standard Swedish: /f/, /s/, /sj/, /tj/, and /rs/
- Voiceless plosives: /k/, /p/, /t/, /tt/

(/h/ is excluded)

Text-to-speech synthesis



Listening test evaluation 1

- 15 subjects, 20 sentences, continuous scale
- Data-driven synthesis with non-corrected formant data was judged more natural sounding than rule-driven synthesis

Listening test evaluation 2

- 12 subjects, 10 sentences, binary scale
- Data-driven synthesis with manually corrected formant data was preferred in 73 % of the cases over rule-driven synthesis

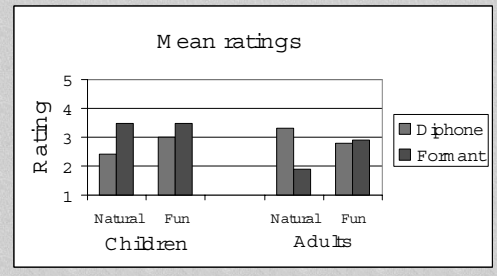
Sound samples

- Strindberg, rule-driven:
- Strindberg, data-driven:
- Strindberg, MBROLA:

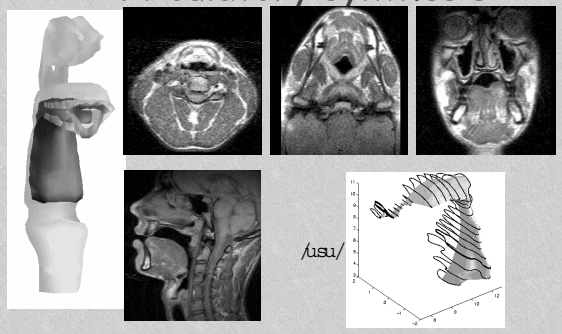
- "Pytteliten", rule-driven:
- "Pytteliten", data-driven:

Child-directed speech synthesis

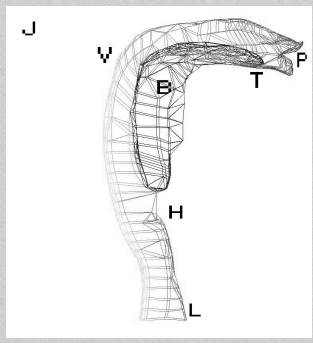
- Increase prosodic variation in synthesis
- How do children between the ages of 9 and 11 react to:
  - default, F0, duration?
  - diphone synthesis vs formant synthesis?



Articulatory synthesis

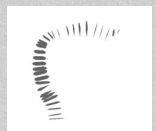


Artikulatoriska parametrar



- Käköppning
- Läpprundning
- Protrusion
- Tungplacering
- Tunghöjd
- Tungspets
- Velum
- Hyoid

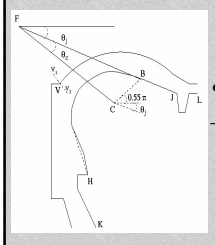
Potentiell användning



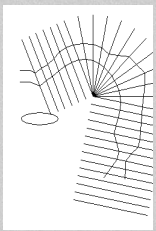
- Artikulatorisk syntes
  - beräkningar direkt från tvärsnittsareorna
  - flödesmekaniska beräkningar

- Visuell Syntes
  - artikulationsträning
  - demonstrationer

Why a 3D model?

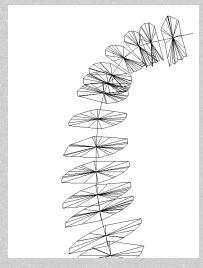


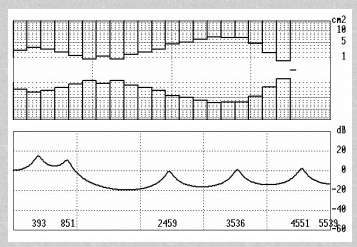
- 2D articulatory models, eg
  - Mermelstein
  - Maeda
- Imposing a third dimension: area = a•(width)^b
- A 3D model:
  - Direct calculation
  - laterals etc.

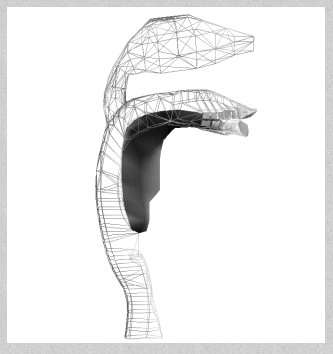


From areas to formants

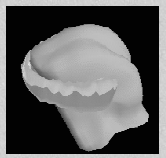
A transfer function is determined from the cross-sectional areas



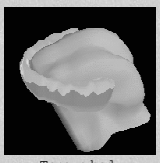




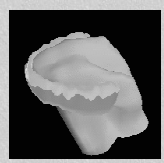
Ranges of parameter activations



Jaw height



Tongue body

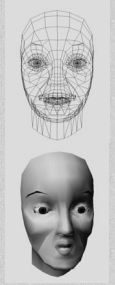


Tongue dorsum

Multimodal talsyntes

Talking heads - Applications

- Improved speech synthesis
- Human-Computer Interface in spoken dialogue systems
- Aid for hearing impaired
- Educational software
- Stimuli for perceptual experiments
- Entertainment: games, virtual reality, movies etc.



A new paradigm for human-computer interaction

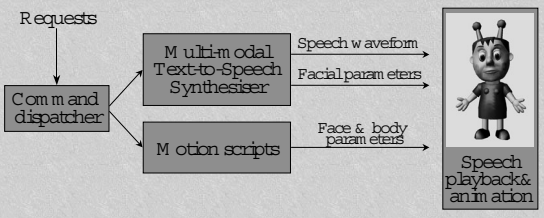
- Shift from desktop-metaphor to person-metaphor
- Spoken dialogue as well as non-verbal communication
- Take advantage of the user's social skills
- Strive for believability, but not necessarily realism

Listening & Thinking

Tasks of an Animated Agent

- Provide intelligible synthetic speech
- Indicate emphasis and focus in utterances
- Support turn-taking
- Give spatial references (gaze, pointing etc)
- Provide non-verbal back-channeling
- Indicate the system's internal state

Animated Character - architecture



Parameters used for articulatory control of the face.

- Jaw rotation
- Lip rounding
- Lip protrusion
- Mouth width
- Bilabial closure
- Labiodental closure
- Upper lip raise
- Lower lip depression
- Apex
- Tongue length
- + more for prosody, attitude, emotions, turn-taking, back-channeling, pointing

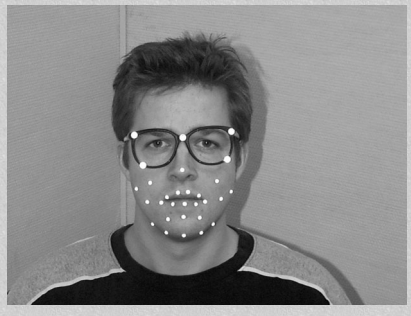
The WaveSurfer Tool

- Interface is based around WaveSurfer, a general purpose tool for speech and audio viewing, editing and labelling
- TTS and Talking Head functionality is added as plug-ins
- WaveSurfer (presently without TTS & TH) works on all common platforms and is freely available as open source

`http://www.speech.kth.se/wavesurfer`

WaveSurfer Tool Demo

How to obtain data?



Qualisys recordings in Linköping

Combining model and data

Re-synthesis using speech movement recorded with Qualisys

pf-star

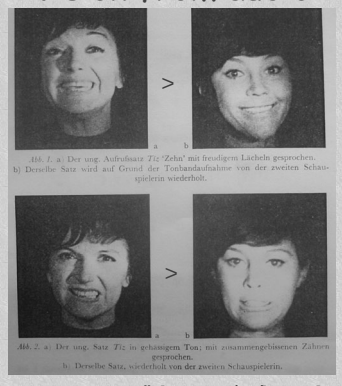
Preparing future multisensorial interaction research

1. technologies for speech-to-speech translation
2. detection and expressions of emotional states
3. core speech technologies for children

EU project: start October 2002, duration 2 YR
ITC-IRST (Trento) co-ordinates + 3*Germany + Italy + UK + Sweden
http://pfstar.itc.it/

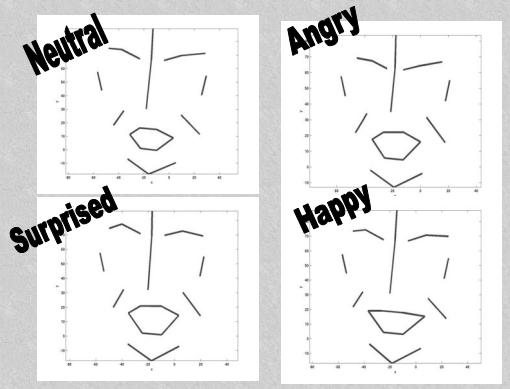
Vision from audio

original

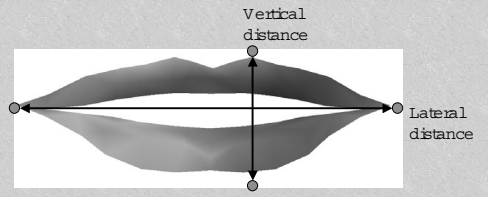


mimic from audio

Fónagy, 1967 "Hörbare Mimik", Phonetica

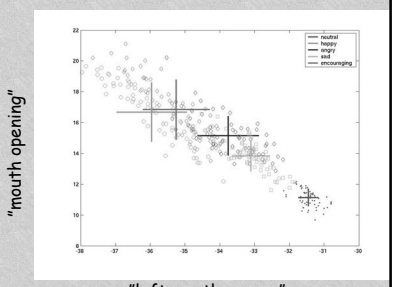


Measurement points for lip coarticulation analysis



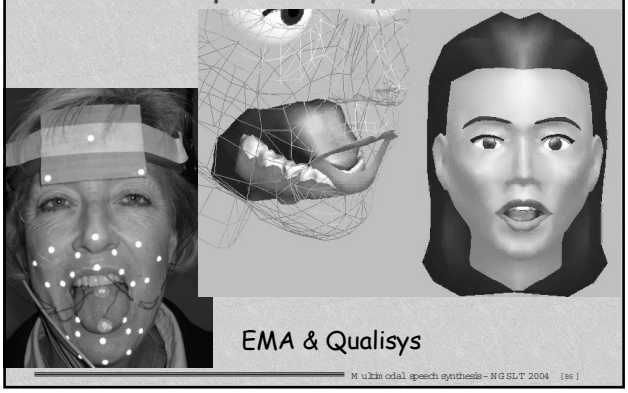
The expressive mouth

- All vowels (sentences)
  - Encouraging
  - Happy
  - Angry
  - Sad
  - Neutral



Interactions: emotion and articulation (from AV speech database – EU/PF_STAR project)

Combining motion capture techniques Example of resynthesis



EMA & Qualisys

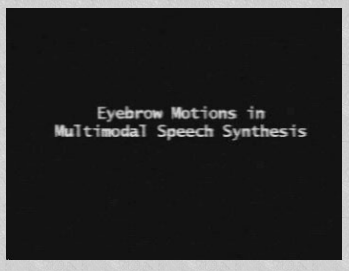
Collection of audio-visual databases: interactive spontaneous dialogues

- Eliciting technique: information seeking scenario
- Focus on the speaker who has the role of information giver
- The speaker seats facing 4 infrared cameras, a digital video-camera, a microphone The other person is only video recorded.

Recording and model

Conversation with agent

Eyebrow vs intonation



1. No eyebrow motion
2. Eyebrow motion controlled by the fundamental frequency of the voice
3. Eyebrow motion at focal accents +
4. Eyebrow motion at the first focal accent +

"Jag heter Axel, inte Axell" (translation: "My name is Axel, not Axell"). In Sweden Axel is a first name as opposed to Axell, which is a family name.

Experiment

- Speech material
  - När pappa fiskar stör, piper Putte
    When dad is fishing sturgeon, Putte is whimpering
  - När pappa fiskar, stör Piper Putte
    When dad is fishing, Piper disturbs Putte
- 6 versions
  - 1 static, 5 eyebrow raising on successive content words
- 20 stimuli (6 x 3) plus first and last
- Subjects: 21 students at KTH
  - 14 native Swedish, 7 non-Swedish

Eyebrow movement

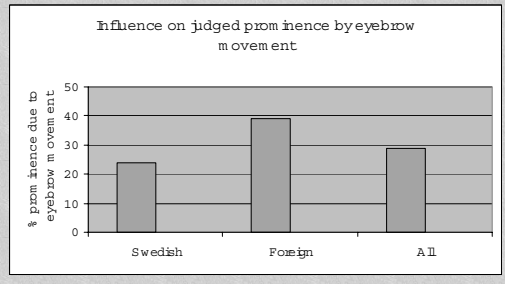
- Hand edited with a synthesis parameter editor
- 500 ms
  - 100 ms dynamic rise
  - 200 ms static raised
  - 200 ms dynamic lowering

TWO EXAMPLES

No eyebrow movement (neutral)

Eyebrow movement

Prominence increase due to eyebrow movement



Conclusions

- Eyebrow movement can be an independent cue to prominence
- Non-native Swedish listeners rely more on the visual cues
- Interaction
  - visual and acoustic cues
  - visual cues and prominence expectation
- Further work on interaction
  - prominence, mood and attitude (demo)

Examples on the use of eyebrow and head motion
(from the August dialogue system)

Translation: "Symmetrical works of art easily become dull just like symmetrical beauties; impeccable or flawless people are often unbearable." (Strindberg 1907)

Different characters

Talande ansikten på Tekniska Museet - Utställningen FrittFram

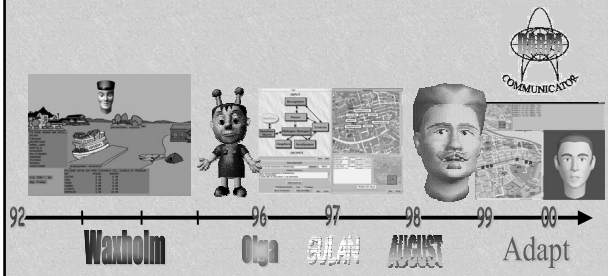
Talteknologitillämpningar - exempel

- Talarverifiering
  - säkerhet
- Översättning eller översättningshjälp
  - språkidentifiering, ämnesbestämning, terminologi
- Studiehjälp
  - tålmodig lärare
  - språkinlärning, uttalsundervisning
- Interaktiva informationssystem /dialogsystem
  - även textgenering
- Indexering och sökning
  - radio och TV program

Talteknologitillämpningar - exempel

- Handikapphjälpmedel
  - synskadade, talskadade, omgivningskontroll
- Telefontjänster
  - kundhjälp
  - intelligenta "telefonsvarare", vem skickar "e-mail"
  - informationssökning, telefonhandling
- "Fria händer"
  - diktering
  - mobiltelefon, trafikinformation
  - sortering, kvalitetskontroll

Dialog systems at KTH



Talteknologi för synskadade

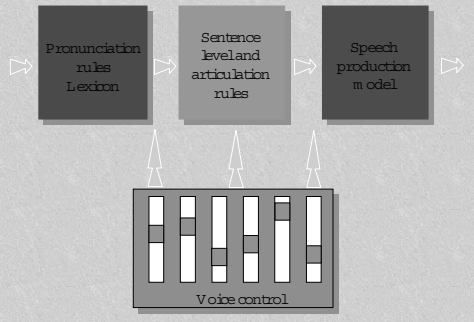
- "Design for all" eller speciella behov
- Första talsyntestilläpningen
- Naturlighet vs. uppfattbarhet
- Skärm läsare vs. GUI
- Talböcker/taltidningar
- Speech browsing, ASR, dialogsystem
- Snabbsyntes - 500 wpm

Talsyntes för talskadade
Cameleon CV - talprotesen från Vaessprojektet

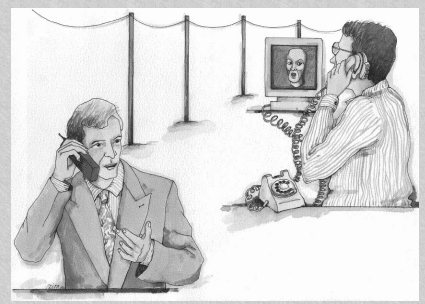
User controlled "voice fitting"

- Direct access to selected voices
- Individual settings easy to use
- Phonetic rules use slide buttons as inputs
- Synthesizer implemented with great flexibility
- Examples of possible adjustments
  - Vocal tract size
  - Voice source characteristics
  - Pitch dynamics
  - Degree of clear or reduced speech

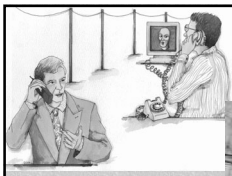
System architecture



Talsyntes för hörselskadade
The Teleface application



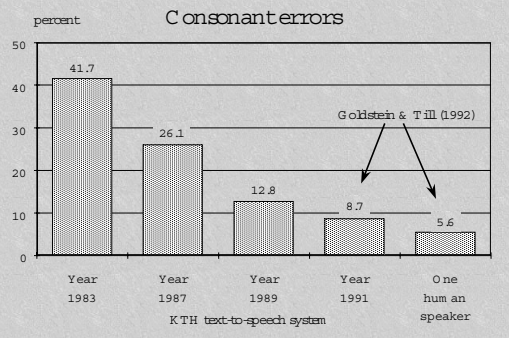
"The TELEFACE project" (simulated)



Multi-modal Speech communication for the hearing impaired

Continues in EU project SYNFACE, aiming at a real-time demonstrator

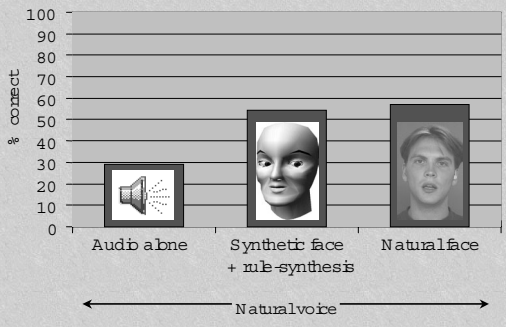
Evaluation of synthesis- VCV test



Formal intelligibility test

- Material: VCV (symmetric vowel context)
  - 2 vowels: /ʊ, a/
  - 17 consonants: /p,b,m,f,v,t,d,n,s,l,r,k,g,ŋ,ɧ,ç,j/
- Task: consonant identification
- Synthetic face with human speech
- hard of hearing subjects (or KTH students)
- Additive white noise, -3 dB SNR (if normal hearing)

Results for VCV-words (hearing impaired subjects)



Better than humans?

aCa

	bil	labd	den	pal	vel
bilabial					
labiodental			3,7		
dental		3,0	78,0	5,5	13,4
palatal			9,9	70,4	19,8
velar			4,9	16,0	79,0

Synthetic face

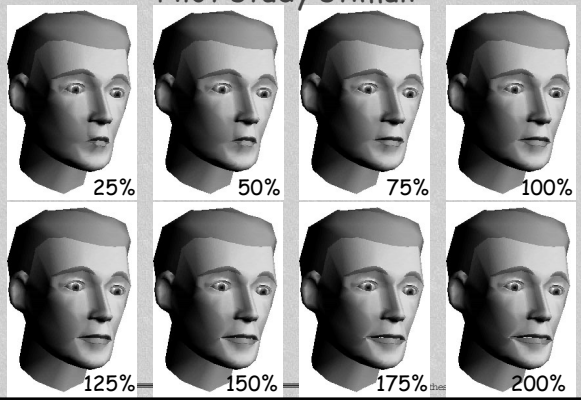
	bil	labd	den	pal	vel
			2,5	1,3	
			5,6	1,9	
			85,8	7,4	6,8
		1,2	17,3	71,6	9,9
			2,5	25,0	72,5

Natural face

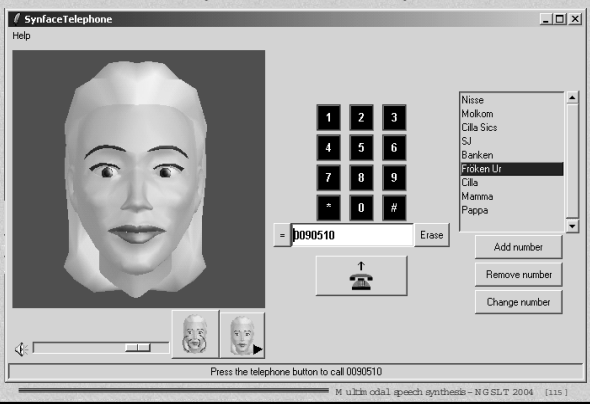
Possible improvements to "lip readability"

- Great variation in human speakers due to for example
  - Speaking rate
  - Extent of articulatory movements (the hypo – hyper dimension)
  - Anatomy, facial hair... .
  - Light, distance, viewing angle...

Hypo to hyper articulation Pilot study stimuli

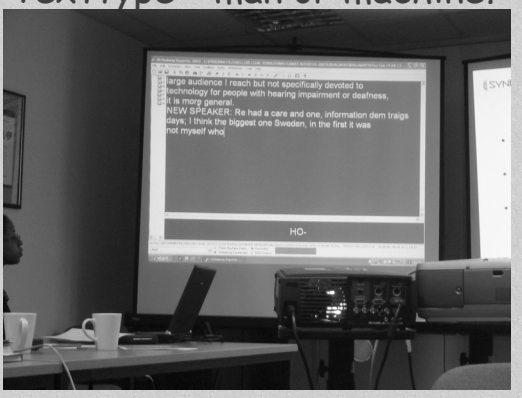


The Synface telephone



Real user tests

Texttype – man or machine?

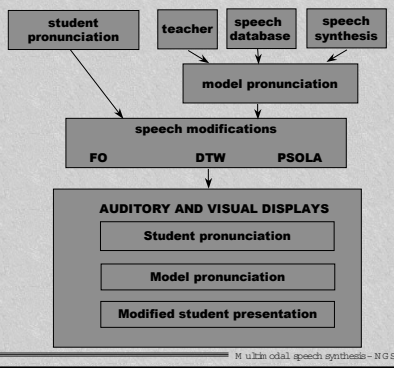


Language learning

- Oral proficiency training
- Possible display of internal articulations
- Exploiting hyper/hypo dimension
- Training in dialogue context
- Always available conversational partner
- Untiring model of pronunciation
  - everything from phonemes to prosody

Speak&Spell - TexasInstrument Christmas 1978

Speech training using intonation models



Demo of prototype

Pohlman - weatherman from the south

"Sen drar hela det här mol- och regnområdet i alla fall vidare österut" (~then, this whole cloud and rain system moves eastward)

1 Original recording

"Teacher" (sound only) -original-modified

2 Stockholm

3 South Swedish

4 Synthesis

1 Original recording

2 Stockholm "Teacher" (sound only) -original-modified

3 South Swedish

4 Synthesis

Articulatory training

- Stylized
- Program Fonem -Johan Liljencrants

Reiko Yamada ATR, 1999

new national project ARTUR

What?

Automatic articulatory feedback display using face and vocal tract models.

For whom?

Hearing impaired children, second-language learners, speech theraphy patients.

How?

Contrasting the user's articulation with a correct one.

CTT Virtual Language Tutor

- Practice dialogues
- Correct your pronunciation
- Keep track of your improvements
- Tailor lessons based on your interaction

CTT Virtual Language Tutor

Different Types of Users:

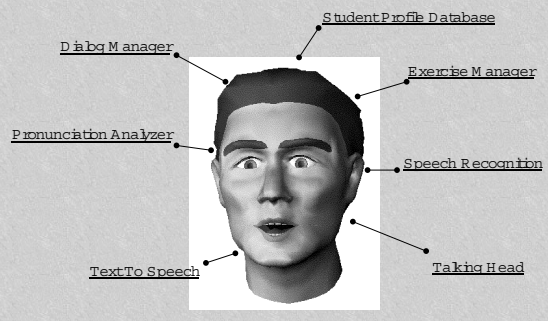
- Swedish children learning English
- Adult immigrants learning Swedish
- Adult Swedes wanting to improve aspects of English (e.g. corporate English, technical English)
- Native Swedes with language disabilities wanting to improve their Swedish

CTT Virtual Language Tutor

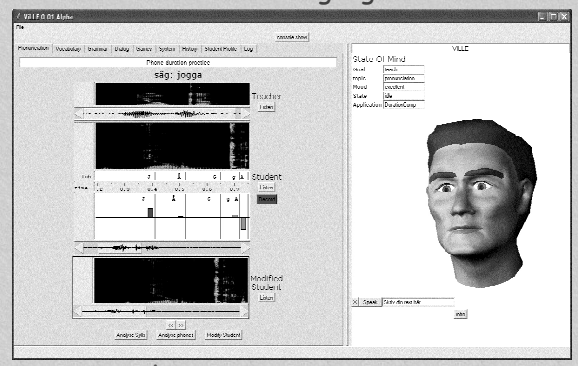
Separate:

- General tools from user specific tools
- Linguistically universal tools from language specific

CTT Virtual Language Tutor components



CTT Virtual Language Tutor



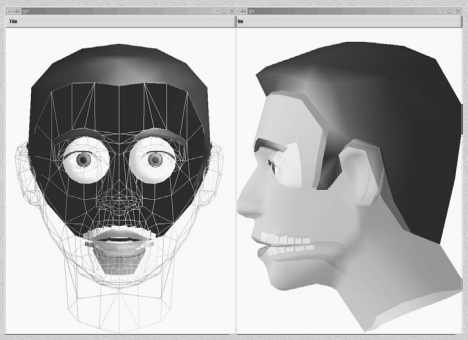
demonstration

Scripted utterances

neutral

question

Different representations



Automatic tutor simulation

no gestures

some gestures

Syntes: slutkommentar

- **Artikulatorisk syntes:** svårt med data, optimal kontroll med gränsvillkor givna!?
- **Formantsyntes:** produktionsrelaterad, flexibel, svårt uppnå naturlighet
- **Konkateneringssyntes -PSOLA/MBROLA:** ej flexibel, hög naturlighet
- Dagens trend: **"Unit selection"** - stora databaser, minimal signalbehandling
- Ökad satsning på högre språkliga nivåer
- "Concept-to-speech" (t ex i dialogsystem)

Bullet course at KTH

Nick Campbell, ATR 20-22 sept 9:30-11:30

1 Language, Speech, and Meaning

In this talk, I shall attempt to describe some of the roles played by prosody in speech communication, and will relate them to the requirements of computer speech processing. The talk covers phonetic, linguistic and paralinguistic aspects of speech.

2 Working with a Corpus of Expressive Speech

This talk describes the JST/CREST Expressive Speech Processing project, introduces a very large corpus of conversational speech and describes some of the main findings of our related research. The talk explores the roles of non-verbal and paralinguistic information in speech communication.

3 Synthesising Conversational Speech

This talk addresses the issues of synthesising non-verbal speech and describes a prototype interface for the synthesis of conversational speech. The synthesised samples are in Japanese, but I believe that they are sufficiently interesting that any inherent language difficulties might be overcome by higher-level speech-related interests.

Summer school in Estonia, August 10-15, 2005

- Organized by the Nordic network VISPP
- VISPP – Variation in speech production and perception
- Focus on how to handle normal and unwanted variation – ASR, pathologies, second language .....
- Palmse conference centre
- http://www.hf.uio.no/ilf/forskning/norfa/

Homework

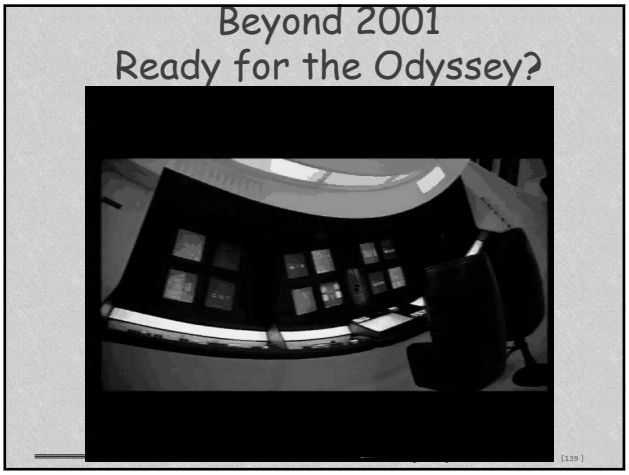
- Experiment with concatenative speech synthesis
- Domain – three digit pronunciation
- Experiment with different unit sizes
- ...different speaking styles – emphatic, emotive, questioning etc.
- To be presented in Stockholm, Jan 2005
- Use WaveSurfer and/or own solutions

HAL'S LEGACY: 2001'S COMPUTER AS DREAM AND REALITY

Chapter 6
"The Talking Computer": Text to Speech Synthesis
Joseph P. Olive

Chapter 7
When Will HAL Understand What We Are Saying?
Computer Speech Recognition and Understanding
Raymond Kurzweil

http://mitpress.mit.edu/e-books/Hal/


Beyond 2001
Ready for the Odyssey?
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