Comparison of tongue contour extraction methods from ultrasound images for use in Text-To-Speech synthesis

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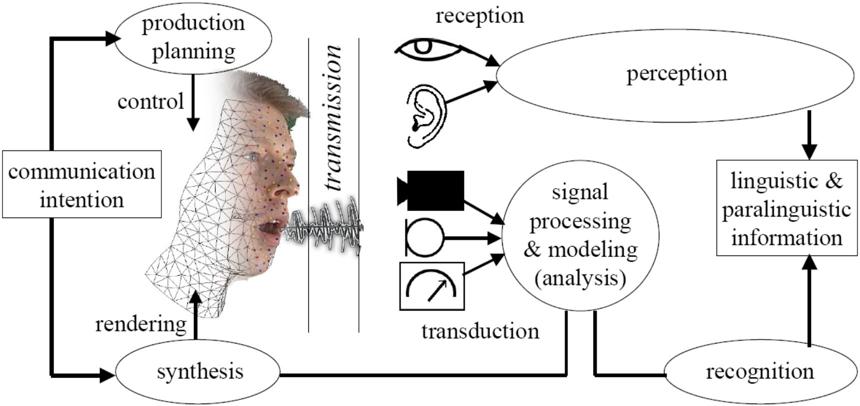
Speech communication chain



[Fagel, 2007]

Text-To-Speech synthesis (TTS) I

- important in human-computer communication
- applications like talking robot, car speech interface
- helpful for the visually and speech impaired people to access and share information
- samples from state-of-the-art technique
  - English (🔊 click)
  - Hungarian (🔊 click)
- highly intelligible
- still far away from natural speech

[Németh and Olaszy, 2010, Zen et al., 2009, Tóth and Németh, 2010]

Text-To-Speech synthesis (TTS) II

Audiovisual TTS

- adding articulatory features might improve TTS quality
- tongue movement
- lip motion
- talking head (click)

[Ling et al., 2009, Schabus et al., 2014]

Speech research with ultrasound I

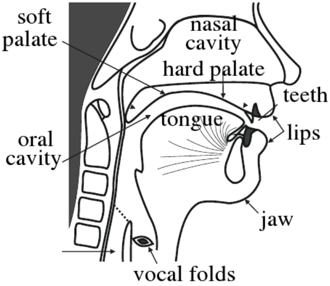
Ultrasound (US)

- used in speech research since early ’80s
- US transducer positioned below the chin during speech
- record video of tongue movement
- series of gray-scale images
- tongue surface has a greater brightness than the surrounding tissue and air

[Stone et al., 1983, Stone, 2005]

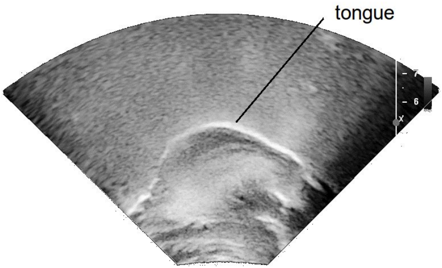
Speech research with ultrasound II

Vocal tract



[Németh and Olaszy, 2010]

Ultrasound sample



(click)

Speech research with ultrasound III

Phonetic research examples

- reconstruct tongue shape during sustained vowels
- investigate speech sounds of under-researched languages
- compare articulatory characteristics of vowels
- analyze tongue shapes for clinical purposes

First step is always the tongue contour tracking!

[Stone and Lundberg, 1996, Mielke et al., 2011, Benus and Gafos, 2007, Zharkova, 2013]

Our goals

This study

- compare manual tongue tracings of several individuals
- compare automatic tongue contour extraction programs
- use 2D ultrasound at high frame rate

Long-term

- extend TTS with tongue contour data based on ultrasound
- include tongue movement in audiovisual speech synthesis (e.g. talking head)
- use real-time 3D ultrasound

Methods

Subjects

- two female and two male
- 3 speakers of American English
- 1 speaker of Hungarian

Speech material

- '*I owe you a yo-yo.*' sentence two times

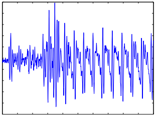
Recordings

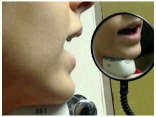
Location

- Speech Production Lab
- Dept. of Speech and Hearing Sciences
- Indiana University

Parallel recordings

- speech signal with a microphone
- video of the lips with a webcamera
- video of the tongue with an ultrasound device (Philips EpiQ-7G, xMatrix 6-1 MHz)





Recording setup

Ultrasound recordings

DICOM video

- 40–45 frames / second
- 800x600 pixels resolution
- 0.2 mm / pixel

JPG image sequence

- altogether 1 145 US tongue images
- (389, 275, 241 and 240 for the 4 speakers)

Manual tracings

Tracers

- 7 individuals (2 authors and 5 students)
- drag a computer mouse cursor
  from the root of the tongue (left)
  to the tip of the tongue (right)
- about 150–200 points per image
- about 5–10 seconds per image

Manual tracing website

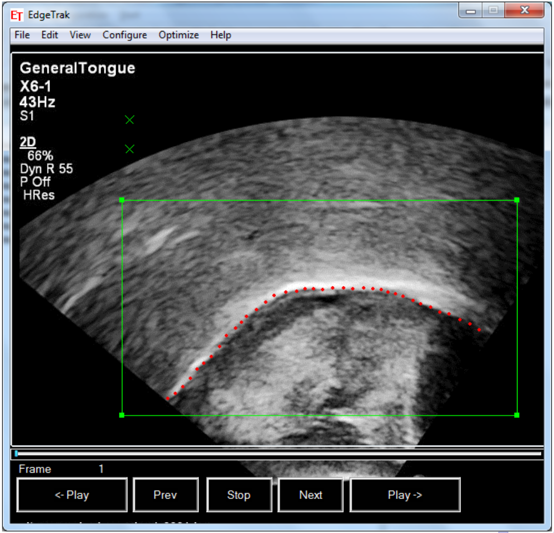
Automatic tongue contour tracking algorithms

4 freely available programs, baseline settings

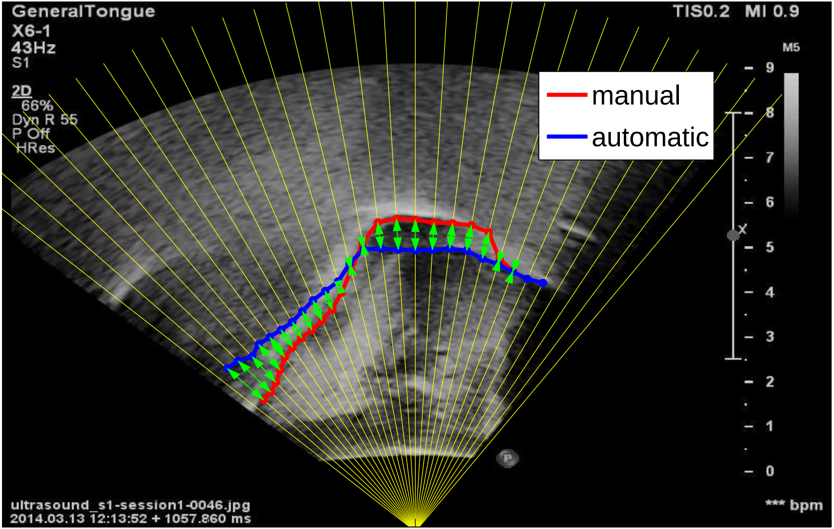
- EdgeTrak (University of Maryland, USA)
- Palatoglossotron (North Carolina State University, USA)
- TongueTrack (Simon Fraser University, Canada)
- Ultra-CATS (University of Toronto, Canada)

[Li et al., 2005, Baker et al., 2005, Tang et al., 2012, Bressmann et al., 2005]

EdgeTrak sample



Comparison of two tongue contours



Manual tracings

RMSE (Root Mean Squared Error) difference from mean

- Average: 7.11 pixel (1.42 mm)
- Std. dev.: 5.07 pixel (1.01 mm)
- depending on the speaker, tracer and image

US video samples

- speaker1 (click)
- speaker4 (click)

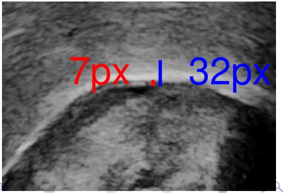
Automatic trackings

RMSE (Root Mean Squared Error)
difference from mean of manual tracing

- Average: 32.30 pixel (6.46 mm)
- Std. dev.: 29.06 pixel (5.81 mm)
- depending on the speaker, program and image
- (compare with: 7.11 pixel inter-tracer variability)

US video samples

- speaker1 (click)
- speaker4 (click)



Average differences of automatic trackings from manual tracings

Table: Average RMSE differences (in pixels)

software	spkr1	spkr2	spkr3	spkr4	avg
EdgeTrak	15.10	9.01	12.00	32.19	17.08
Palatoglossotron	33.11	46.60	86.84	95.82	65.59
TongueTrack	14.86	14.73	20.48	19.50	17.39
Ultra-CATS	57.98	34.67	36.71	38.27	41.91

(compare with: 7.11 pixel inter-tracer variability)

Summary

This study

- ultrasound recordings with 4 speakers
- compared manual tongue tracings of 7 individuals
- compared 4 automatic tongue contour extraction programs

Future plans

- extend Hungarian / English Text-To-Speech with tongue contour data
- use 2D / real-time 3D ultrasound
- include tongue movement in audiovisual speech synthesis (e.g. talking head)

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    - Adam Baker, Tim Bressmann, Jeff Mielke, Maureen Stone, Lisa Tang
- Manual tracing website
    - Hao Lu

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