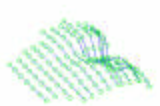

3D ultrasound on a budget: Reconstruction of 3D tongue shapes from multiple coronal planes

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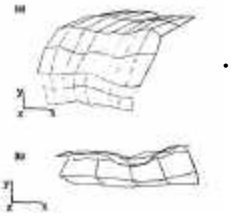
Willy Wong, Ph. D.

The tongue – a three-dimensional muscular hydrostat

Literature Review

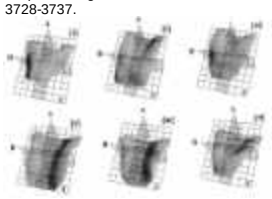
Watkin, K.L. & Rubin, J.L. (1989) "Pseudo-three-dimensional reconstruction of ultrasonic images of the tongue," J. Acoust. Soc. Amer., 85, 496-499.



- Reconstructed tongue surface during production of sustained /s/

Literature Review

Stone, M. and Lundberg, A. (1996) "Three-dimensional tongue surface shapes of English consonants and vowels," J. Acoust. Soc. Amer., 99, 3728-3737.



- 60 coronal slices at 1 ° intervals

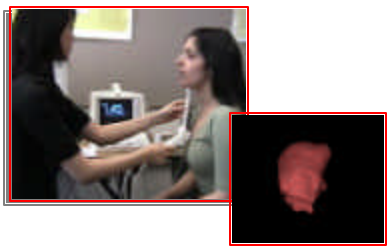
Lundberg, A. and Stone, M. (1999) "Three-dimensional Tongue Surface Reconstruction: Practical Considerations for Ultrasound Data," J. Acoust. Soc. Amer., 106, 2858-2867.

- Accurate tongue surfaces may be reconstructed from ultrasound data using as few as 6 coronal slices

Literature Review

Our 3D Method: 3D Echotech FreeScan system

Bressmann, T., Thind, P., Uy, C., Bollig, C., Gilbert, R.W., Irish, J.C., (2005). "Quantitative three-dimensional ultrasound analysis of tongue protrusion, grooving and symmetry: Data from 12 normal speakers and a partial glossectomee," *Clinical Ling. & Phon.*, 19, 573-588.



Literature Review

Lengthy data preparation and processing time for relatively few data points per 3D volume

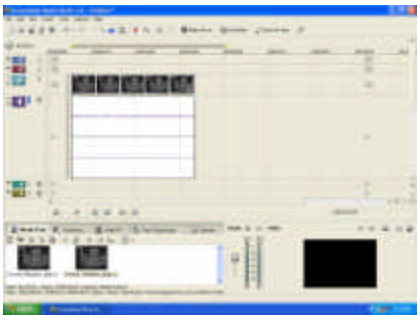
… and then, the motion transducer broke.

A new approach (for us) to the acquisition of 3D tongue surface data

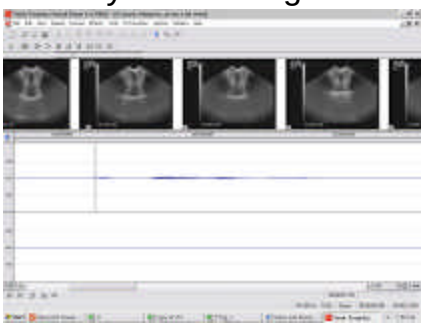
- Criteria
  - Accessibility and cost of machinery → 3D technology too expensive (GE VoluSon, Phillips iU22)
  - Participant comfort with head stabilization
  - Ease and speed of data collection and analysis

New CHASE 2 head anchor

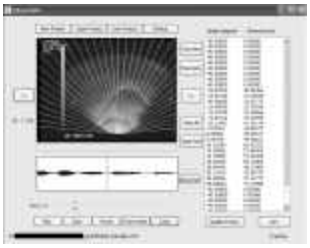
Segmentation of movies using ScreenBlast 3.0



Identification of frames using Sony SoundForge 6.0



Data measurement in Ultra-CATS

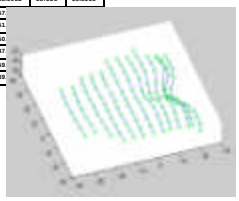


- The Ultra-CATS software was used to trace the tongue surface at each target frame as identified in SoundForge
- The Ultra-CATS converted the line tracing into a set of data points according to a grid with 5 degree intervals that radiated from the centre of the transducer
- Ultra-CATS download: www.flintbox.org

3D reconstruction using MATLAB

- MATLAB was used to convert the measurement data generated by Ultra-CATS into 3D surface plots

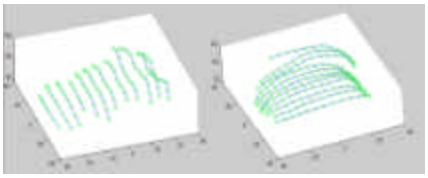
i25	i20	i15	i10	i05	center	r05	r10	r15	r20	r25
0	0	60.3633	60.3633	61.1011	61.3527	60.6199	60.3633	60.3633	0	0
0	56.0907	56.4805	58.3762	60.6199	60.8696	61.1011	59.3279	59.0638	0	0
0	56.0907	55.5472	56.3895	57.6906	57.971	57.6906	58.3762	59.0638	59.1447	0
55.9762	56.0907	56.4805	58.3762	57.2092	55.5556	56.7278	59.3279	58.4721	58.526	59.2157
0	58.526	58.0052	58.3762	57.2092	55.0725	56.2465	59.3279	58.4721	58.526	0
55.3346	55.4715	56.0137	55.9136	52.3548	50.2418	53.3593	56.8655	58.0052	58.526	59.6535
55.7736	55.6374	54.9558	53.927	50.4293	49.2754	49.9481	53.927	57		
0	51.9633	51.5643	50.0368	46.5376	41.0628	40.239	45.5876	51		
49.4975	49.8171	49.5729	45.5876	36.8704	34.7826	34.4218	37.2482	50		
49.4975	49.3829	48.5141	44.0357	35.8661	34.2995	34.4218	37.2482	47		
57.056	57.6177	58.0052	58.852	55.7652	54.5915	54.8027	58.852	59		
0	45.6899	44.531	41.6973	34.9032	34.2995	33.9404	35.345	39		



Ultra-CATS output and MATLAB plot for the sound /i/

Sagittal or coronal scans?

- Sagittal slices are easier to view and trace; however:
  - Sagittal-based reconstructions for sustained speech sounds often yield skewed results
  - The midsagittal groove of tongue is difficult to capture accurately with sagittal slices



Coronal scans Sagittal scans

Goals of the current study

(1) Evaluation of 3D reconstructions from coronal scans

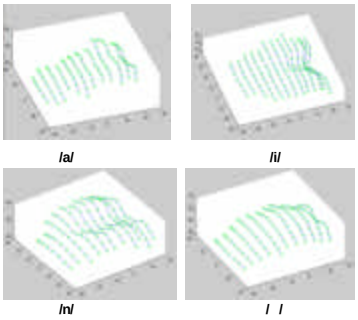
(2) Evaluation of head stabilization using the CHASE 2

Evaluation of 3D reconstructions from coronal scans

Participants and method

- 3 participants were recruited (2 female, 1 male)
- Head was stabilized in the CHASE 2 (Johnson, 2006)
- 5 English speech sounds : /a/, /i/, /u/, /n/, / / were sustained for 13 seconds each (3 repetitions)
- Coronal scans were collected by pivoting the transducer in five degree intervals from 25 degrees anterior to 30 degrees posterior

Sample tongue surface reconstructions



/a/ /i/

/n/ / /

Composite Measures

Anteriority

$$\sum_{n=1}^{5} \left[\frac{5y_A + 4y_B + 3y_C + 2y_D + y_E}{y_A + y_B + y_C + y_D + y_E} \right]$$

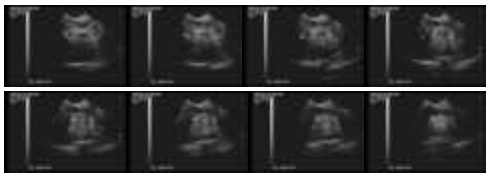
/a/	/i/	/u/	/n/	/ /	GrandAverage
8.81 (0.09)	9.12 (0.13)	8.91 (0.09)	9.06 (0.05)	8.99 (0.07)	8.98 (0.12)

- Highest value: /i/
- Lowest value: /a/
- Anteriority of /u/ found to be between /i/ and /a/
- /n/ ranked 2nd highest in anteriority
- Results similar to data of normal participants in Bressmann et al., (2005)

Composite Measures

Concavity

/a/	/i/	/u/	/n/	/ /	GrandAverage
11.15 (6.74)	19.9 (21.68)	6.51 (12.87)	24.96 (27.49)	-8.91 (14.87)	9.9 (14.7)

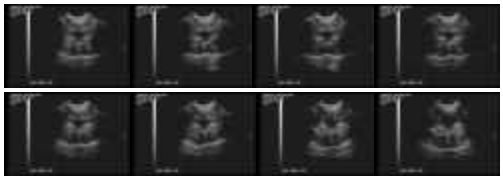


Concavity during sustained production of /n/

Composite Measures

Asymmetry

/a/	/i/	/u/	/n/	/ /	GrandAverage
12.9 (10.28)	19.6 (10.9)	20.6 (14.65)	10.5 (5.78)	21.45 (20.02)	17.01 (4.97)



Asymmetry during sustained production of /a/

Variability

- Expected margin of error: 2mm
- Mean overall inter-trial variability: 2.1 mm (*SD* = 1.22 mm) across all sounds
- Maximum mean variability: 5.63 mm
- Minimum mean variability: 0.79 mm

Discussion

- Composite measures of concavity and asymmetry showed differences across participants → may be a reflection of individual differences in orofacial anatomy
- Anteriority and inter-trial variability values were in agreement across participants
- Data acquisition with the CHASE 2 shortens the process of data acquisition considerably (from ca. 30-45 minutes using the FreeScan system to under 15 minutes using the CHASE 2)
- Faster, less onerous data analysis

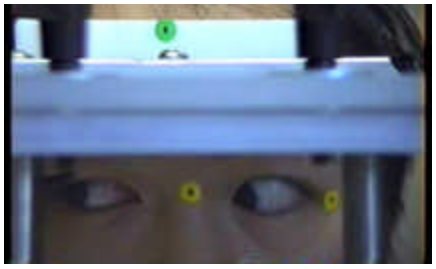
Evaluation of head stabilization using the CHASE 2

Participants and methods

- 2 female participants were recruited (ages 23 and 24)
- Head was stabilized in the CHASE 2 (Johnson, 2006)
- 5 English speech sounds : /a/, /i/, /u/, /n/, / / were sustained for 13 seconds each (3 repetitions)
- Coronal scans were collected by pivoting the transducer in five degree intervals from 25 degrees anterior to 30 degrees posterior
- One participant also read the Grandfather Passage with the transducer held at 0 degrees.
- Head movement was recorded continuously using a digital camera

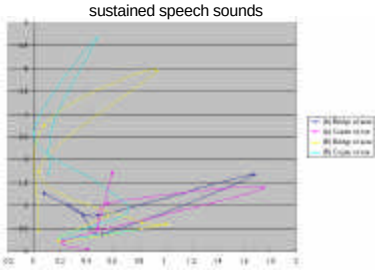
Data analysis

Semi-automatic measurement of vertical and horizontal head movement using NIH ImageJ



Results (1)

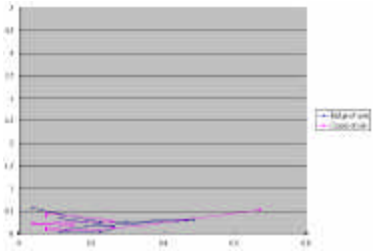
Horizontal and vertical head movement of participants A and B during sustained speech sounds



Mean horizontal movement: 0.5 mm (*SD* = 0.44 mm); Max: 1.75 mm; Min: 0 mm
Mean vertical movement: 1.32 mm (*SD* = 1.15 mm); Max: 4.7 mm; Min: 0.04mm

Results (2)

Horizontal and vertical head movement during passage reading task



Mean horizontal: 0.2 mm (*SD* = 0.16 mm); Max: 0.67 mm; Min: 0.04 mm
Mean vertical: 0.24 mm (*SD* = 0.16 mm); Max: 0.56 mm; Min: 0.04 mm

Discussion

- Minimal horizontal head movement during both tasks→ CHASE 2 headset provides sufficient head stabilization in a compliant subject
- Pivoting transducer eliminates the need for a stand-off pad between the transducer and chin
- Vertical deviations were in an acceptable range. Some vertical movement is to be expected, related to mandibular opening.

Future directions

- Use of new methodology on patient populations (e.g. glossectomee patients)
- Construction of a motor for the pivoting transducer holder for faster data acquisition

Questions?

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