OVERLAYING ULTRASOUND TO MRI SEQUENCES

Jim Lee
Maureen Stone
University of Maryland Dental School
March 20, 2010
Ultrafest
Goal: Maximizes advantages of both MRI and Ultrasound imaging.

+ Ultrasound: Fast tongue motion and copious data
+ MRI: visualizes other vocal tract structures

The result would be a midsagittal vocal tract that reproduces a single repetition of real time speech.
GOALS OF THE STUDY

- To accurately map the US tongue into the MRI vocal tract
- Method: to register the ultrasound palate to MRI palate
  - The palate is the common structure in both images.
  - The registration parameters are applied to ultrasound tongue images
  - These transformed US tongue contours are compared to the MRI tongue contours
# Advantages and Disadvantages of Ultrasound (US) and MRI

<table>
<thead>
<tr>
<th>US Advantages</th>
<th>US Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Portability</td>
<td>• Not all structures are visible (Ex. Tongue tip and posterior pharyngeal wall)</td>
</tr>
<tr>
<td>• Inexpensive</td>
<td></td>
</tr>
<tr>
<td>• Fast</td>
<td></td>
</tr>
<tr>
<td>• Easy to use</td>
<td></td>
</tr>
<tr>
<td>• Comfortable and noninvasive</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MRI Advantages</th>
<th>MRI Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• All structures are visible: vocal tract can be extracted</td>
<td>• Expensive</td>
</tr>
<tr>
<td>• Multiple planes (convenience)</td>
<td>• Supine data collection</td>
</tr>
<tr>
<td></td>
<td>• Claustrophobia</td>
</tr>
<tr>
<td></td>
<td>• Multiple repetitions are needed or slow frame rate or Poor resolution</td>
</tr>
</tbody>
</table>
Subject position: In MRI, the subject is supine while in US, the subject is sitting up

- In the present data set, supine MRI and supine ultrasound were available for both subjects.
- If the ultrasound and MRI data sets could be aligned, an ultrasound tongue could be used with an MRI vocal tract.
- In the future, maybe an upright ultrasound data set could be aligned with a supine MRI vocal tract.
CHALLENGES IN OVERLAYING MRI TO ULTRASOUND

- **Frame rate:** MRI used in study operated at 12 Hz while US operated at 30 Hz
  - Both MRI and US can be operated at faster speeds. But it will not be uncommon to have mismatched frame rates
**CHALLENGES IN OVERLAYING MRI TO ULTRASOUND**

- **Slice thickness**: A MRI slice width is 6 mm in thickness while a US slice thickness is 1.9 mm.

  + Midsagittal groove: A midsagittal tongue groove will look shallower on MRI.
CHALLENGES IN OVERLAYING MRI TO ULTRASOUND

- **Angulation**: In US, the transducer is tilted at an angle under the chin, thus the data do not match the MRI head angle
  - In this data set, a neck brace was used to hold the US transducer and the same neck brace was used in the MRI but without the transducer to reproduce head position
  - However, palatal alignment is meant to correct even an uncontrolled head position as long as the midsagittal plane is lined up and the head does not move.
METHODS

1. Convert midsagittal MRI and US image sequences into the same spatial coordinates: Enlarge and crop MRI jpegs
2. Extract and track tongue and palate contours from MRI and US images.
3. Align US tongue contours to MRI tongue contours using palatal alignment parameters.
   1. Transform US palate contours to MRI palatal contours using translation and rotation.
   2. Apply those transformations to the US tongues
4. Align US tongue contours directly to MRI tongue contours using rotation and translation for validation.
5. Compare palate-based transformations to tongue-based transformations with RMS differences.
METHODS: PROGRAMS UTILIZED

- **Image J**: for enlarging and cropping the MRI images. If only dicom images are available, Image J can be used to convert these images to jpegs.
- **Edgetrak**: contour tracings for palate and tongue for MRI and ultrasound images
- **Excel**: Managing contour coordinates on spreadsheet
- **Pal_aln (Matlab)**: Rigidly aligning and transforming the palatal contours and tongue contours
- **Cavite (Matlab)**: Comparing aligned contours and determining RMS differences
**METHODS: DATA SETS**

- **Subjects:** MRI images were scaled to the same dimensions as the US images.
  - **Palatal contours:**
    - MRI: hard palate and soft tissue of the soft palate
    - US: Bony interface of the hard palate during the repetitive movement of the subject drinking water (“swallow”)
  - **Tongue contours:**
    - SML: Sounds “IA” and “AU” (MRI/Ultrasound)
    - LLT: Sounds “IA” (MRI/Ultrasound)
- **Comparisons:**
  - SML and LLT: Both subjects were compared using the sound “IA”
  - “IA” and “AU”: both sounds were compared through the same subject (SML)
METHODS: MEASUREMENTS

- Edgetrack was used to measure the contours of the palate and tongue for both MRI and Ultrasound.
- 7 tongue contours were selected from both US and MRI for each sound. Ex. For the sound “IA”: Frame 1-2: contained “ee” / Frame 3-5 contained the transition / Frame 6-7 contained “a”
- Each US tongue contour was matched with a MRI tongue contour.
METHODS: MEASUREMENTS

Pal_AlIn was used to transform the US palatal contours to the MRI palates using rigid body rotation and translation (left). The transformation parameters were then applied to the US tongue contours to align them to the MRI palates (right).
TWO METHODS OF CALCULATING RMS WERE CONSIDERED

The 2 y values were compared at each x.

Nearest Neighbor subtraction compared closest xy.
RMS showed better results for Nearest Neighbor method.

Nearest Neighbor

- **LLT_IA**
  - Ave. RMS Error = 5.07 mm

- **SML_IA**
  - Ave. RMS Error = 3.25 mm

- **SML_AU**
  - Ave. RMS Error = 3.24 mm

Y at Each X

- **LLT_IA**
  - Ave. RMS Error = 6.15 mm

- **SML_IA**
  - Ave. RMS Error = 4.2 mm

- **SML_AU**
  - Ave. RMS Error = 4.86 mm
Differences were seen between subjects (LLT, SML) but not tasks (/IA/, /AU/)
PALATE TRANSFORMATION WAS BETTER FOR SML THAN LLT COMPARED TO DIRECT TONGUE TRANSFORMATION

**Palate to Palate**

**LLT_IA**

RMS Error = 5.07 mm

**SML_IA**

RMS Error = 3.25 mm

**SML_AU**

RMS Error = 3.24 mm

**Tongue to Tongue**

RMS Error = .98 mm

RMS Error = 1.64 mm

RMS Error = 1.84 mm
CONCLUSIONS

- Why is one subject better?
  - SML palates were more similar on MRI and US.
  - Ultrasound palate was from a different task than US tongue. It was extracted from a swallow. Palatal alignment may have been less effective for LLT if the transducer was not in the same position in the swallow and in the “IA” and “AU.”

- This method may be appropriate for some subjects and not others

- Future study: move to more complex tasks such as words to see if they are aligned as well as vowels.