Background & Objective

- “ATR MRI database of Japanese vowel production” has been released for academic purposes.
- Based on this database, the transfer function of the 3D vocal tract has been studied by numerical analysis methods. However, the accuracy of the simulation have not been thoroughly examined.
- To provide a benchmark of the acoustic properties of the vocal tract, we measured the transfer function of solid vocal tracts constructed from the MRI database.
- This is one of the reliable methods to obtain the vocal tract transfer function in detail.

3D MRI data

stereo-lithographic technique

solid vocal tract model

acoustic measurement

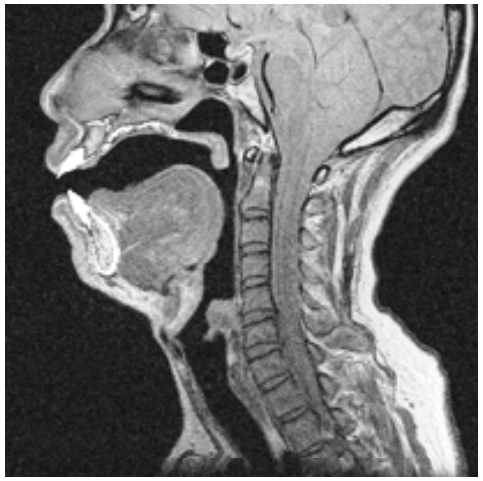
transfer function

ATR MRI database of Japanese vowel production(2005)

- Volumetric MRI data and vowel sounds
  - vowel: the five Japanese vowels (/a/, /e/, /i/, /o/, & /u/)
  - subject: a male native Japanese speaker
- MRI data acquisition techniques
  - Phonation synchronized scanning (Masaki et al., 1999, Takano et al., 2006)
  - Bone-conduction stimulus presentation (Nota et al., 2007)
- The database has been released for academic purposes.

Fig. 1 Mid-sagittal image of the vowel /a/.

The database were acquired at and released from ATR Human Information Science Labs. under "Research on Human Communication" founded by the NICT, Japan.



/a/

/e/

/i/

/o/

/u/

Parameters

- slice thickness: 2.0 mm
- no slice gap
- no averaging
- field of view: 256x256 mm
- image size: 512x512 pixel
- no. of slice: 51
- flip angle: 90 º
- echo time: 11 ms
- repetition time: 3,000 ms

How to make the solid models

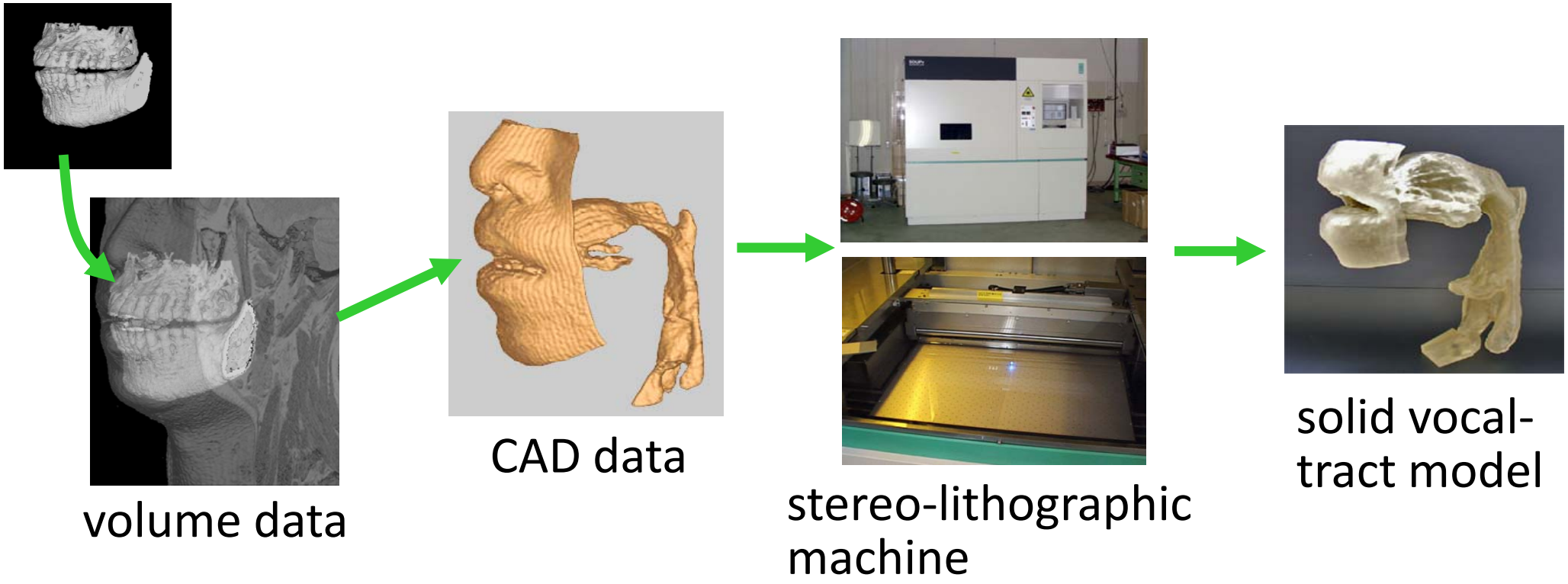


Fig. 2. Process for forming the solid vocal-tract models.

Materials of the solid model

- an epoxy resin (D-mec Ltd., SCR735)
- density: 1.19 g/cm3 @ 20 ^{o}C
- speed of sound: 2,352 m/s @ 25.5 ^{o}C

Measurement method

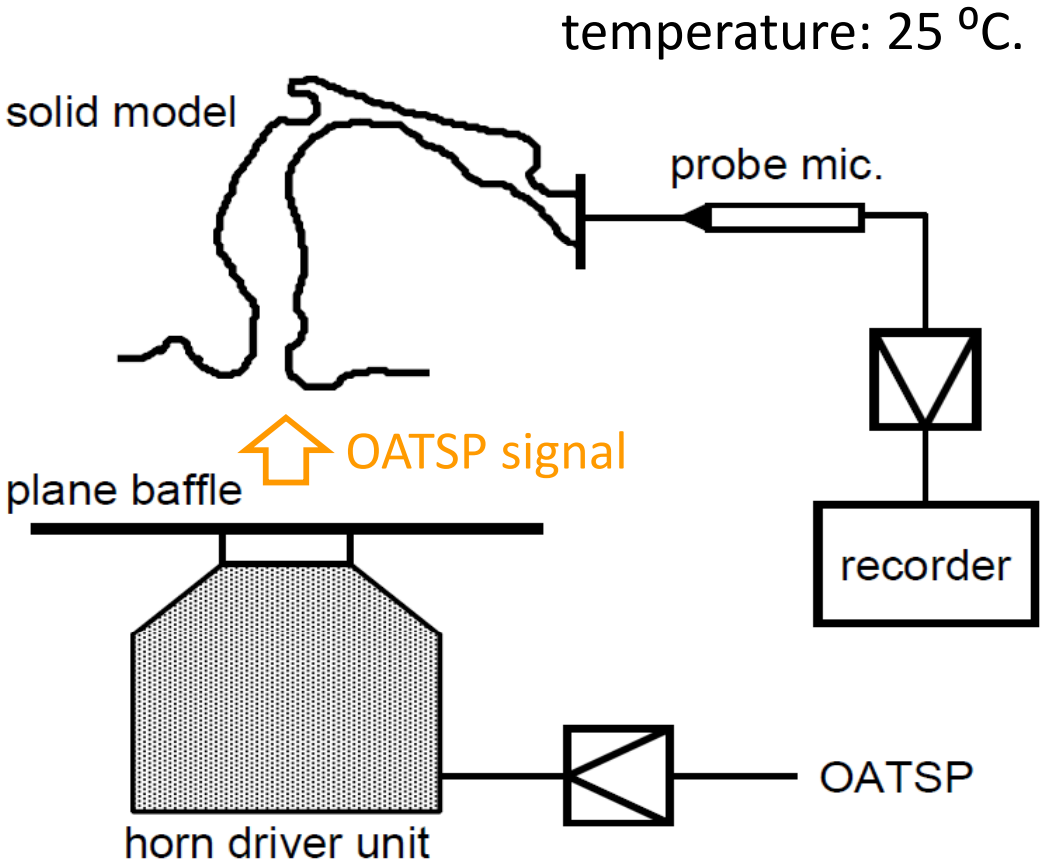
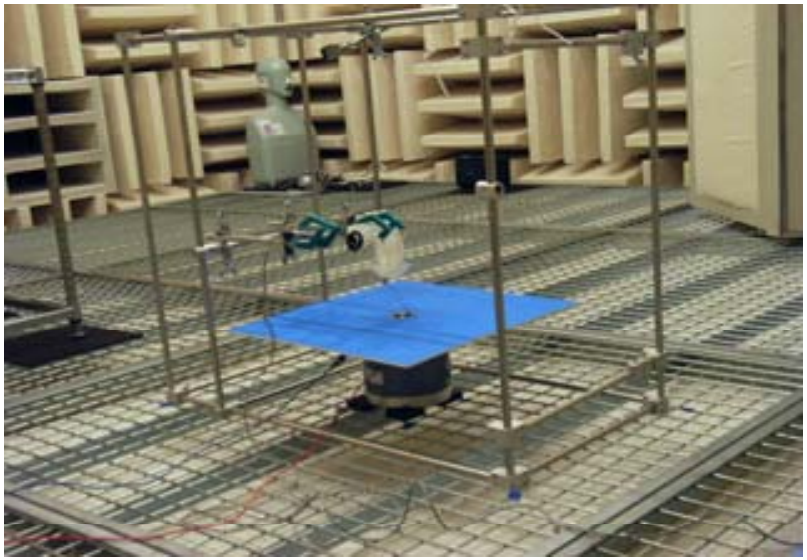


Fig. 3. Measurement setup.



Measurement method

- A 0.34-ms optimized Aoshima's time-stretched pulse (OATSP) (Suzuki et al., 1995) was introduced into the solid model at the lip end.
- The response was measured at the glottis of the solid models.
- The glottal impedance set high to suppress the acoustic effects of glottal opening.
- The measured transfer function equals $2p_s(\omega)$ times as much as the volume velocity transfer function.
  - The resonance and anti-resonance frequencies are constant between the two transfer functions.

Acoustic effects of vocal fold vibration on the laryngeal cavity resonance

- The laryngeal cavity resonance: a resonance that occurs with in the laryngeal cavity during vowel production (Takemoto et al., 2006).
- The laryngeal cavity resonance appears under the closed-glottis condition and disappears under the open-glottis condition (Kitamura et al., 2006).

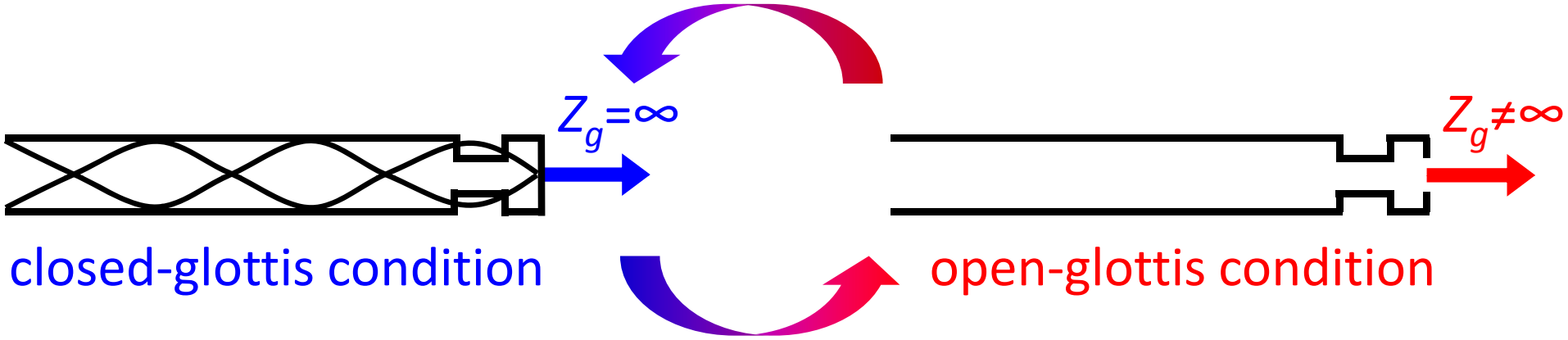


Fig. The laryngeal cavity resonance is generated when the glottis opens and is dumped when the glottis closes.

Speech spectra

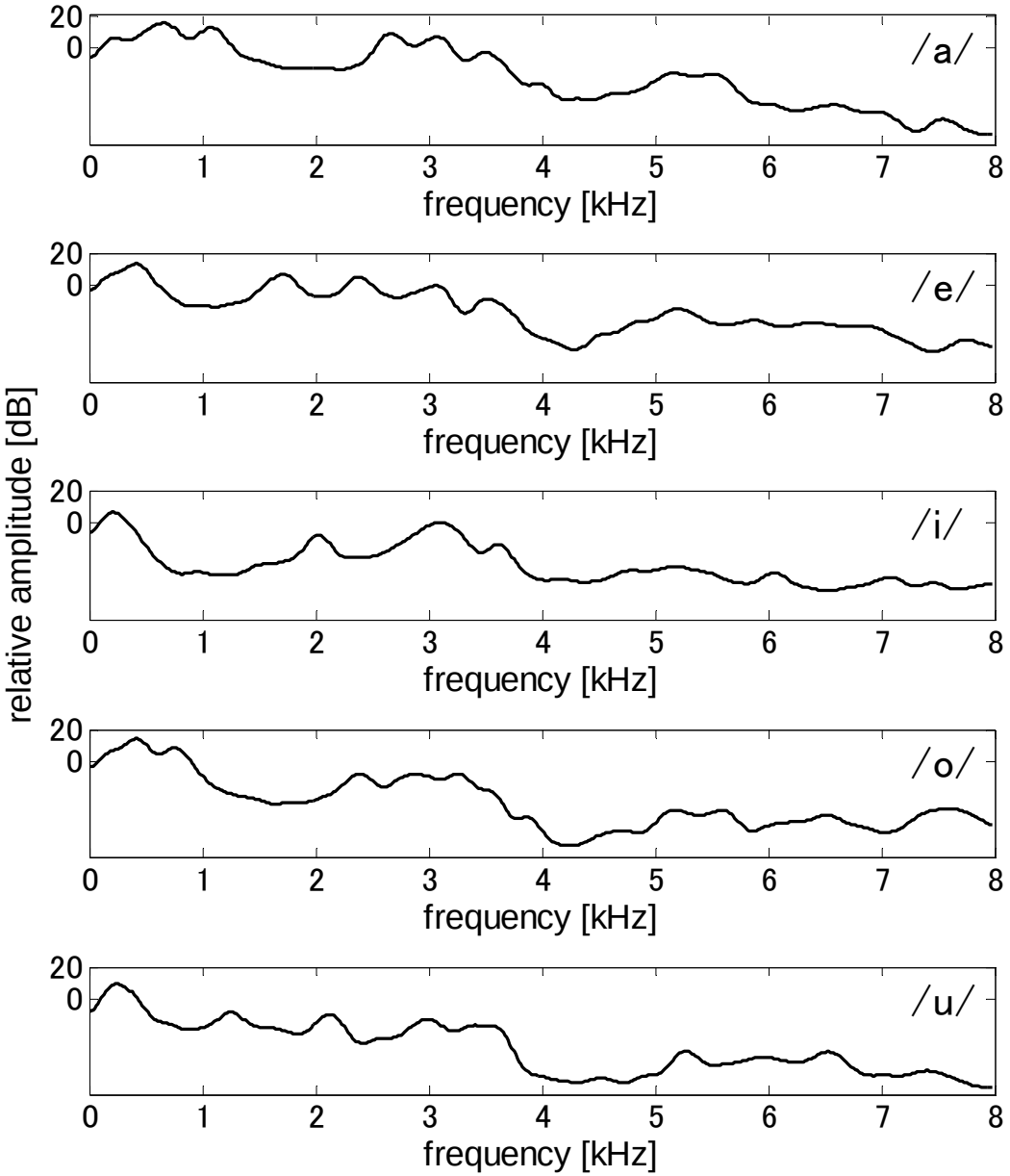


Fig. Spectral envelopes of the five vowel s

Table The first, second, third, and fourth formant frequencies (F1, F2, F3, and F4) of the five vowels [Hz].

vowel	F1	F2	F3	F4
/a/	656	1,078	2,656	3,078
/e/	406	1,719	2,375	3,062
/i/	203	2,031	3,094	---
/o/	421	750	2,391	2,875
/u/	234	1,250	2,125	3,000

Conclusion

- The transfer function of the solid vocal tracts constructed from “ATR MRI database of Japanese vowel production” was measured.
- This results provide a reliable benchmark for numerical analyses of vocal tract acoustics using the database.
- Note that the transfer functions are different from those of the human vocal tract:
  - the physical models have the solid wall.
  - the radiation characteristics at the lips could be different.
  - the velopharyngeal port of the solid model for the vowel /a/ was closed.

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References

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