Physical Models Producing Vowels with Pitch Variation

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Abstract

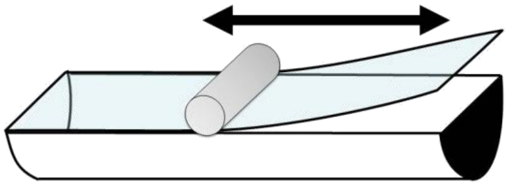
Physical models of the human vocal tract are useful for education in acoustics and speech science. To excite such vocal-tract models, different types of sound sources may be used. We have developed two new types of physical models which produce a glottal source with a variable fundamental frequency. Both types are based on a reed vibration, and the length of the vibratory portion can be varied manually. In the first type, the reed itself is curved, while the reed of the second type is straight but its support is curved. In each case, we can demonstrate vowel production with pitch variation by combining vocal-tract models with our proposed source models.

Index Terms: physical model, vocal-tract model, sound source, fundamental (pitch) frequency, vowel production, education in speech science

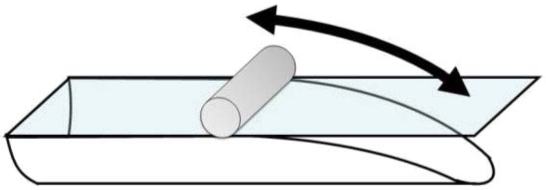
1. Introduction

We have developed different types of physical models of the human vocal tract and shown that they are useful for education in acoustics and speech science [1]. With these models, we can demonstrate several important aspects in speech science, such as, the source-filter theory and the relationship between vocal-tract shape and vowel quality. When teaching the source-filter theory, it is effective to show students that the variation in fundamental frequency of an input signal directly affects the pitch variation of the resultant vowel. Therefore, a sound source with a variable fundamental frequency plays an important role. Furthermore, it is useful to teach students vowel production of not only a particular speaker group but also a variety of speaker groups from children through adults. In general, an adult male speaker has a lower pitch, an adult female speaker has a relatively higher pitch, and children and infants have even higher pitch [2]. Thus, the optimal fundamental frequency for different vocal-tract length varies; the shorter the vocal-tract length, the higher the optimal fundamental frequency.

Different types of sound sources are available, and we have tested them in our previous studies [e.g., 1]. An electrolarynx is one of the more useful sound sources. Although many types of electrolarynges have a constant vibratory frequency, some types can vary the frequency, so that the resulting pitch contour is not monotonic. A whistle-type artificial larynx is another kind of sound source. In this case, a natural pitch contour can be made depending on the pressure of the air that is fed into the device. Another option is to use a loudspeaker with an arbitrary signal used as a source signal. However, the loudspeaker-based sound source system may be cumbersome, inconvenient, and less intuitive.



(a) Version 1



(b) Version 2

Figure 1: *Schematic figures of two versions of variable length reed-type sound source: (a) Ver. 1 and (b) Ver. 2.*

In this study, we designed two physical models of the sound source which have pitch variation. With these models, we can demonstrate source-filter theory, speech production with intonation, different speakers—from children through adults, and even singing.

2. Designs

We designed two types of physical models for the sound source with vibratory frequency varying in time. Riesz designed an artificial larynx with a curved reed clamped at one end where the sliding clamp could change the effective length of the vibrating reed [3]. In the current study, for our first model type, we re-designed the Riesz model to make a variable length reed-type sound source (Ver. 1) as shown in Fig. 1(a).

As we discussed in [4], there is another reed-type sound source, the support of which, rather than the reed, is curved. While we cannot continuously change the effective length of the vibrating reed of the original model in [4], our second new design features a variable length reed for this sound source with a curved support (Ver. 2), as shown in Fig. 1(b).

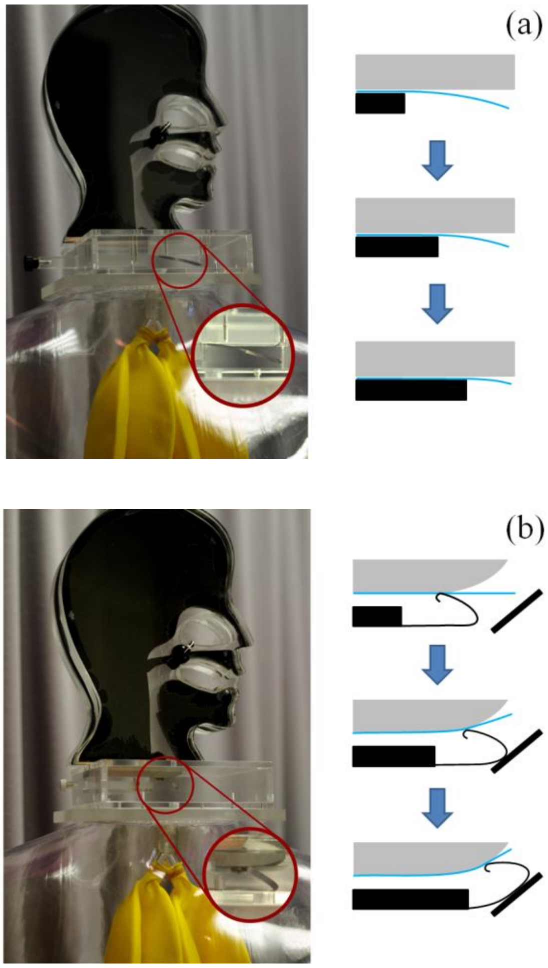


Figure 2: *Source models that we implemented in the current study: (a) Ver. 1 and (b) Ver. 2.*

3. Implementation

Figure 2 shows the source models that we implemented in this study. Each source model in Fig. 2 is attached to a head-shaped model, configured for /a/, and a lung model. The airflow from the lungs sets the reed vibrating, and the sliding bar controls the effective length of the reed. Figure 3 shows spectrograms of the vowel /a/ with fluctuated pitch produced by the implementations in Fig. 2. In Fig. 3, we can clearly see the formants of this vowel as steady horizontal dark bars and the pitch variation as a shift of each harmonic component.

4. Discussion

These proposed sound source models make a significant contribution to education in speech science. With them, we can produce vowels with varying intonation. We also can teach source-filter theory by demonstrating that pitch variation comes from the change in the fundamental frequency of a sound source by attaching and detaching the sound source from a vocal-tract model. Additionally, because these models produce a wide range of fundamental frequency, vowels of children through adults can be produced with a single model. Finally, the models can also produce a singing voice.

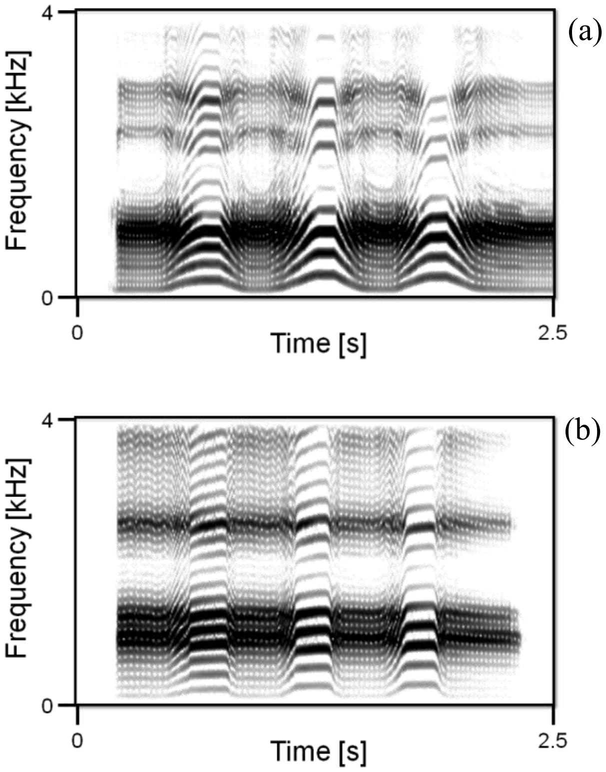


Figure 3: *Spectrograms of vowel /a/ with fluctuated pitch: (a) Ver. 1 and (b) Ver. 2.*

5. Conclusions

In this study, we designed two versions of the variable length reed-type sound source. By combining them with vocal-tract models, we were able to produce a vowel, changing its pitch manually. When combined with the vocal tract models we have already developed, whose vowel quality may be changed manually, now we are able to manually control both the pitch and vowel quality simultaneously.

6. Acknowledgements

This work was partially supported by Grants-in-Aid for Scientific Research (21500841) from the Japan Society for the Promotion of Science, and Sophia University Open Research Center from MEXT.

7. References

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