Interspeech 2018
2-6 September 2018, Hyderabad

Flexible tongue housed in a static model of the vocal tract with jaws, lips and teeth

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Abstract

Physical models of the human vocal tract with a moveable tongue have been reported in past literature. In this study, we developed a new model with a flexible tongue. As with previous models by the author, the flexible tongue is made of gel material. The shape of this model's tongue is still an abstraction, although it is more realistic than previous models. Apart from the tongue, the model is static and solid; the gel tongue is the main part that can be manipulated. The static portion of the model is an extension of our recent static model with lips, teeth, and tongue. The entire model looks like a sagittal splice taken from an artificial human head. Because the thin, acrylic plates on the outside are transparent, the interior of the oral and pharyngeal cavities are visible. When we feed a glottal sound through a hole in the laryngeal region on the bottom of the model, different vowels are produced, dependent upon the shape of the tongue. This model is the most useful and realistic looking of the models we've made for speech science education so far.

Index Terms: physical models of the human vocal tract, flexible tongue, gel material, education in speech science

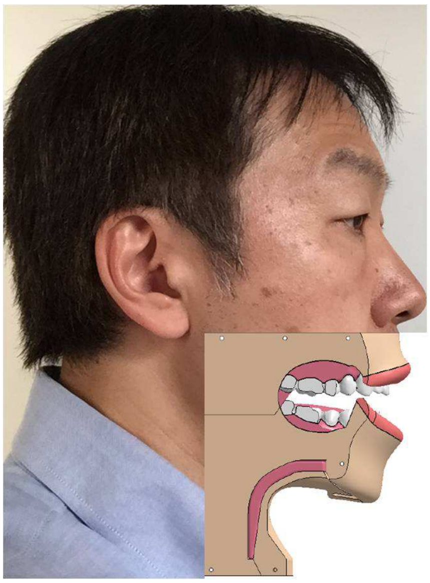


Figure 1: *Side view of the proposed model of the human vocal tract overlaid on the top of a facial picture*

1. Introduction

We have developed a series of physical models of the human vocal tract (e.g., [1-3]). They were successfully used to demonstrate acoustic theories and phenomena, as well as mechanisms in acoustic phonetics. Several physical models of the vocal tract reported on in past literature have had a moveable tongue [4,5,6,7], including previous studies by the author [3,7], where flexible-tongue models were developed and used in pedagogical situations.

In this study, we have designed a new model with a tongue made of gel material. Although the shape of the tongue is more realistic than our previous model, it is still an abstraction of an actual tongue. In addition to the tongue, the bottom of the oral cavity and the anterior pharyngeal wall were also made of gel material. However, the tongue is the main part a user can manipulate to change its shape. Because the anterior pharyngeal wall is also made of gel and the shape of the pharyngeal cavity can therefore be changed by pushing the tongue against it. The rest of the physical model is static and solid. The static part of the current model is an extension of our recent static model with lips, teeth, and tongue [8]. We designed this new model and demonstrated its usefulness for education in speech science.

2. Designs

The target model is partially moveable and able to produce different vowels depending on vocal tract configuration. To design such a model, we combined two of our previous models: the one proposed in [7] and the other proposed in [8]. Figure 1 shows the side view of the proposed model of the human vocal tract overlaying a picture of a face. Figure 2 shows the main part of the model viewed from three different angles.

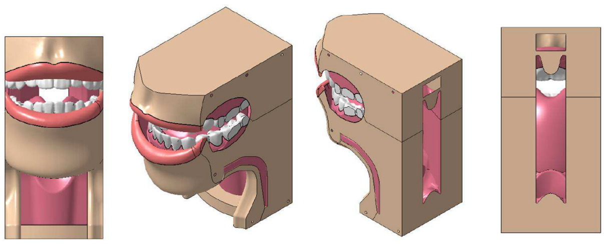
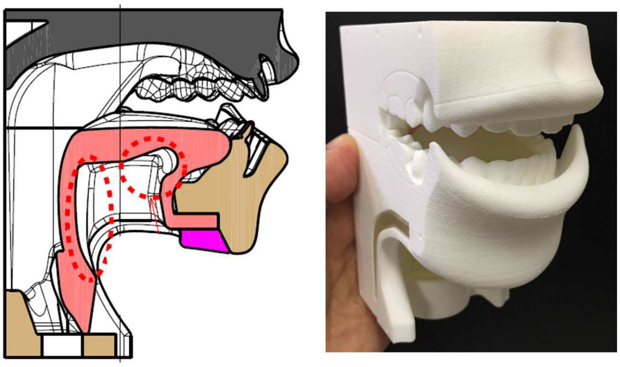


Figure 2: *The proposed model viewed from different angles.*



(a) (b)

Figure 3: *(a) Mid-sagittal cross-section of the proposed model. (b) Photograph of a prototype.*

3. Discussion and Conclusion

As you can see in Figure 2, transparent plates are attached to the outside, making windows in the sagittal surfaces. Because the cover plates are transparent, the inside of the oral cavity is visible from the outside. We also added coloring for each articulator for easier identification.

Figure 3(a) shows the mid-sagittal cross-section of the proposed model. The dark color is put in this figure to show the cross-section of the tongue. As you can see in this figure, a semicircular groove was designed on the top surface of the tongue along the mid-sagittal plane as was done in [7]. This groove helps to produce high-front vowels because when the tongue is raised and in high position, the groove and palate form a long narrow constriction. To produce low vowels, we can pull the tongue body down. For back vowels, because the anterior part of the pharynx is also made of gel material, we can push the tongue root back to make a narrow constriction in the pharyngeal region. Figure 3(b) shows a prototype of the proposed model created by a 3D printer.

Because the proposed model is more realistic looking, it has great potential for applications in education in speech science and acoustic phonetics, and additionally, for pronunciation training in language learning. The tongue is flexible, so it is easy to manipulate it to form different vocal-tract configurations for foreign vowels. It can also be used for speech therapy in the clinical domain, as well as for an introductory explanation at a science workshop for children. Figure 4 shows a picture of our previous model [8] taken from the event called "Science Square" held at the National Museum of Nature and Science (Tokyo, Japan) in summer, 2017. For children, this kind of realistic looking attracts them and helps to intuitively understand the articulation including the tongue position (and the tongue movement with the proposed model).

Figure 4: *The static version [8] used at the "Science Square" (the National Museum of Nature and Science, Tokyo, Japan) in summer, 2017.*

Although the current model has a velum and uvula, they are static in this model. In our previous study [9], we proposed another model with a moveable velum made of gel material. In the future, we would like to incorporate a similar design into the proposed model in the present study, along with a nasal cavity. We have already started to design a model with moving lower jaw and lips. It will be a challenge to determine the best way to implement this mechanically, without losing the high intelligibility of vowels we enjoy with the current model. Implementing a moveable jaw and lips is another part of our future work.

4. Acknowledgements

This work was partially supported by JSPS KAKENHI Grant Numbers 15K00930 and 18K02988.

5. References

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