An ultrasound probe headset prototype with damper for speech research

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Introduction

Ultrasound imaging in speech research requires the probe to be held under the chin to observe the shape and movement of the tongue. Many types of headsets for holding the probe still have been proposed for speech research even in recent years [1-5], and most of them were designed to keep the probe in a constant position relative to the head throughout an experiment. However, the probe tip can dig into the skin when the mouth is open in such headsets. This makes the position of the probe relative to the lower jaw unstable during measurement, meaning that the measuring origin of ultrasound images is floating [5]. This increases measurement errors, such as underestimating the downward movement of the tongue. Besides, the probe not only restricts the movement of the lower jaw but can also cause pain to the skin.

This study attempted to address the problems by providing a damper in the probe-holding part of a headset. The authors developed a headset prototype and evaluated how the damper worked by comparison with a commercially available ultrasound probe headset.

Articulatory-friendly probe headset

The proposed headset is mainly characterized by a damper with a spring attached to a probe clamp. The damper allows the probe to move vertically with the mandible during speech. This mechanism is expected to help maintain a constant probe position relative to the lower jaw and avoid disturbance of the mandible movements caused by the probe during speech.

Figure 1 shows an isometric drawing and photo of the proposed headset. The headset used a head strap from a commercially available face shield, contributing to cost reduction and ease in production. Adjustable straps were attached to the front, sides, and back of the headset to accommodate people with different head sizes and shapes, including children and adults, as well as long and short heads. The visor of the face shield was also kept as it was, and the downward-extending arms were attached to each side. Each arm has three screw-adjustable joints for precise probe position and orientation adjustment.

The horizontal unit connected to the lower ends of the arms, and a probe clamp with a built-in damper was attached to the center of the unit. The horizontal position of the probe clamp is adjustable within a few centimeters. Sagittal and coronal tongue imaging is available by holding the probe in the corresponding orientation. The spring tension can be adjustable by changing the length of the spring. These parts are made of lightweight ABS resin and produced by a 3D printer.

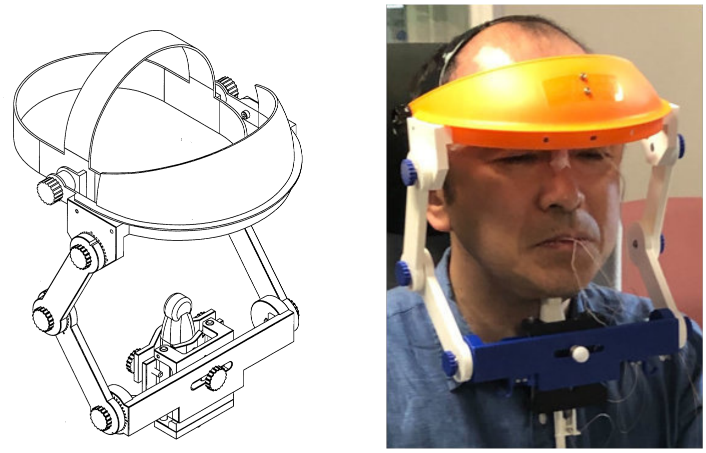

Figure 1: (left) Isometric drawing of the proposed headset. (right) Photo of the proposed probe headset prototype in place. The probe is fixed to the probe clamp with a damper and moves upward and downward following the mandible movements.

Method of evaluation

The temporal three-dimensional position of the probe relative to the nasion and mandible was measured by an electromagnetic articulography (EMA) (Northern Digital Inc., Wave Speech Research System [6]) for a male native Japanese speaker producing voice with two headsets. A micro convex probe (GE Healthcare, 8C-RS) was fixed in the sagittal direction using a commercially available headset, UltraFit [3], and the proposed one. Ultrasound gel was applied to the tip of the probe. A 40 mm x 200 mm anti-seismic elastomer gel sheet was inserted between the speaker's forehead and the head strap to reduce the slipping of the headsets.

The reference sensor (6 degrees of freedom, 6DOF) of the EMA system was fixed on the nasion, and three 5DOF sensors were fixed on the alveolar ridge of the lower incisor and lateral premolar teeth. Two other 5DOF were fixed on the probe in the direction of its longitudinal axis at a distance of 65.5 mm.

The speaker was seated, and his head was located by the field generator of the EMA system. After closing his mouth, he repeatedly produced Japanese /ai/, /pa/, /ta/, and /ka/. The 3D position of the 5DOF sensors relative to the reference sensor was measured at a sampling rate of 100 Hz.

Results and discussion

Figure 2 depicts the sagittal trajectory of the 5DOF sensor stuck on the upper part of the probe measured while the speaker repeatedly produced the Japanese vowels /ai/ wearing the two types of headsets. The sensor's position was normalized by its initial position. The figure demonstrates the effects of introducing the damper in the probe clamp; the probe's height was lowered to 4 mm following the vertical motion of the lower jaw for the proposed headset, while the probe's height was almost fixed for UltraFit. On the other hand, the probe moved backward and forward for about 9 mm with the open-close motion of the lower jaw for the back and front vowels for both headsets. The motion was possibly due to the elasticity of the material of the parts of the headsets.

Figure 3 shows the distance between the upper part of the probe and the plane defined by the sensors' positions on the alveolar ridge of the lower incisor and left and right premolar teeth. A smaller distance means that the probe tip got closer to the mandible; that is, it dug into the skin more. The results suggest that it may be difficult to maintain a stable position of the probe tip relative to the mandible, even if the damper was built into the probe clamp. Still, the proposed headset might effectively reduce the restriction of the movement of the lower jaw. It corresponds with the participant’s report that he felt less pain when he used the proposed headset than when UltraFit fixed the probe.

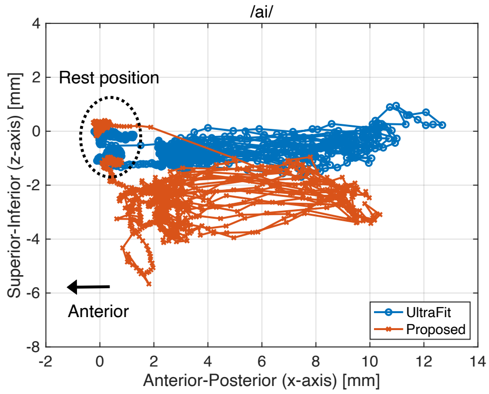

Figure 2: Trajectory of the upper part of the probe relative to the initial position measured during repetition of Japanese vowels /ai/ in the sagittal plane. The left side of the figure is the anterior of the speaker. The blue and red lines indicate the trajectory for UltraFit and the proposed headset, respectively.

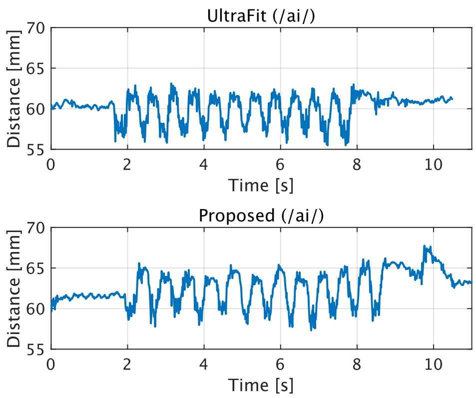

Figure 3: Distance between the upper part of the probe and mandible during repetition of Japanese vowels /ai/. Top: UltraFit, bottom: the proposed headset.

Conclusion

This study developed an ultrasound probe headset that allowed the probe to follow the lower jaw movement by the damper of the probe clamp. The authors carried out the preliminary feasibility test by tracking the movement of the probe and lower jaw using the EMA system and showed that the damper worked to some extent but needed to be improved. Our next steps are to find the appropriate physical properties of the spring for the probe holder and compare the articulatory motion with and without the headset.

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