

**Translation Of 3-D Articulatory Signals Acquired By Electromagnetic Articulography To A Visual Display Of Lingual Movements For Biofeedback: Preliminary Results**

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**Oral presentation Preferred but will accept either Oral or Poster Presentation**

**Key Words:** Electromagnetic articulography, Lingual biofeedback, Motor (re)Learning

**Preferred Track:** Speech Motor Control.

**Audiovisual Equipment Required:** LCD projector

**Brief Author Bios:**

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**Ge Jin**, Ge Jin is a doctoral student in the Department of Computer Science, The George Washington University. His areas of interests are: image-guided surgery, surgical simulation, computer animation and image based rendering in computer graphics. He received his MS in Computer Science from the Seoul National University in 2000, and BS in Computer Science from Beijing University in 1997.

**Jared Kiraly**, is a senior in the Department of Computer Science, The George Washington University, pursuing a degree in computer science with a concentration in digital media. He was awarded an Institute for Biomedical Engineering Summer Fellowship in 2005 for his project titled "Motion Capture and Analysis of Lingual Movements for Biofeedback During Speech Using Electromagnetic Articulography".

**Bahne Carstens and Brigitta Carstens**, are the owners Carstens Medizinelektronik, GmbH, Lenglern, Germany, Founded in 1979, for the development, manufacture and distribution of the electromagnetic measurement systems Articulograph AG100 and AG500, systems for visualizing, registering and analyzing speech movement inside the mouth.

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### **ABSTRACT:**

The number of persons who suffer a speech production impairment following neurologic damage is extremely high. The evidence base for the efficacy of articulation remediation in neurogenic speech disorders is insufficient. Traditional techniques for re-training speech rely primarily on the adequacy of auditory feedback to shape articulatory movements of the tongue, lips, jaw, and soft palate. Failure of such techniques to generalize or to be maintained may be the result of neurological damage that impairs the ability to accurately utilize auditory feedback to shape articulator movements during speech re-learning. Visual (bio)feedback of lingual movement of one's own speech and/or that of others might therefore be effective in establishing and promoting more accurate speech. However, one of the most difficult aspects of speech to convey visually is lingual movement in the oral cavity. The latest electromagnetic articulography system (AG500) can track articulatory movement in 3-dimensions. The purpose of this preliminary study was to demonstrate that lingual movement signals acquired by the AG500 can be translated into visual representations of lingual movement that subjects could use as biofeedback during speech (re)learning. We will discuss the development of the translation programs and demonstrate the preliminary data collected from models and from several non-impaired speakers.

Key Words: Electromagnetic articulography, Lingual biofeedback, Motor (re)Learning

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### **Proposal Summary**

There are approximately 5-6 million persons in the US who suffer a speech production impairment that is the direct result of neurologic disorders such as stroke, traumatic brain injury (TBI), and Parkinson's disease (PD)<sup>1,2,3,4,5</sup>. Given the high incidence of and the negative effects (social isolation, reduced quality of life<sup>6</sup> loss of employment and exclusion<sup>7</sup>) from these speech impairments, it is critically important to provide efficacious remediation techniques to those individuals.

Overall, the evidence base for the efficacy of such remediation techniques is insufficient (lacking in evidence for generalization and maintenance of treatment gains) particularly as it relates to articulation of speech<sup>8,9,10,11</sup>. (The exception is the well documented treatment efficacy studies of the LSVT® in PD<sup>12</sup> and other neurologic disorders<sup>13</sup>.)

Failure of traditional therapy techniques to generalize or to be maintained following treatment cessation may be the result of neurological damage that impairs the ability of these persons to accurately utilize auditory feedback to shape articulator movements during speech re-learning<sup>14,15</sup>. Given the degradation of this "normal" auditory based speech motor learning system<sup>16</sup>, the addition of visual (bio)feedback of lingual movement would likely prove more effective in rehabilitation than auditory feedback of one's voice alone or such auditory feedback with auditory modeling. Given the success of visual feedback in limb motor learning studies (in healthy<sup>17,18,19,20,21</sup> and neurologically damaged individuals<sup>22</sup>) and in the remediation of VPI<sup>23</sup>, it is likely that visual (bio)feedback of lingual movements would be effective in establishing more accurate speech utilizing another modality (vision) to shape accurate articulatory movements.

One technique for delivery of lingual biofeedback is by electromagnetic articulography (EMA). EMA systems have become the gold standard for non-invasive digital recording, presentation and evaluation of the movements of the articulators during the production of speech and have been used in research involving normal<sup>24,25,26</sup> and disordered speech production<sup>27,28,29</sup>. To date the one study of the use of EMA<sup>30</sup> (AG100) in the remediation of adult neurogenic speech production disorders suggested that this type of visually guided biofeedback regarding tongue position and movement may be beneficial<sup>31</sup>. However, the visual feedback provided was abstract; that is it did not look like a tongue moving, but was rather a line moving on a computer screen. The AG100 could only record and display two dimensional lingual movement in the midsagittal plane.

The newest EMA, the AG500 overcomes the limitations of the AG100, namely it records articulatory movement in 3-dimensions, thus the data generated can be used to develop visual representations of lingual movement. The purpose of this preliminary study was to demonstrate that lingual movement signals acquired by use of the AG500 can be translated into visual representations of lingual movement.

## **METHOD**

A clay model of the tongue was made and 6-8 sensors were attached to it with tape. Three were attached across what would be the equivalent of the dorsum (one on the extreme right, one in the midline and one on the extreme left); three were attached across what would be the equivalent of the tongue blade in the same manner; one was attached to what would be the equivalent of the tongue tip, one was attached beneath under the mid-blade position, and two were attached to each side. Following calibration of the AG500, the clay tongue model was moved in the measuring area and these movements were recorded.

Lingual movements from one non-neurologically impaired participant was then recorded. Sensors were placed in various configurations on this participant's tongue to determine which positions would yield the most representative placements for use in the computer translational programs. One of the limitations of the AG500 system is that the sensors must be placed 8mm from each other or there will be interference and signal distortion. To overcome this we always placed one sensor was approximately 0.5 mm from the tip of the tongue and placed 3-4 more on the participant's tongue then recorded multiple repetitions of the words "monarch butterfly" and "pataka". Then we took off all but the tongue tip sensor and placed the sensors in 3-4 other positions on the tongue and recorded the speech samples again.

Following corrections for head movements which are independent from speech, the measured points are rotated by an additional program so they correspond to the three coordinate planes of motion (x (anterior-posterior); y (superior-inferior); and z (lateral-medial)). Using the relevant sensor positions as control points, radial basis function deformation is applied to a graphical model, causing it to take the shape of the tongue. Radial basis function deformation is a series of functions that causes all points on a model to move with a control vertex, with points closer to the control vertex being more strongly affected by its movement. The radial basis functions are applied to successive sample points on the model, causing the tongue model to move.

## **RESULTS**

Recordings made with the clay model yielded the most visually "real" translations of "lingual" movement. That is, when the translation programs were applied to the data generated from the sensor positions on the clay tongue model, the resulting animation of that movement looked very much like a moving tongue.

To visualize the lingual motion of tongue from the human participants, we modeled the 3D shape of tongue using MAYA 3D modeling software. The observed sensor position before speech, worked as reference point in this modeling stage. Recorded sensor movement from the human participants drove the 3D tongue model to deform using radial basis function. Compared with individually plotted sensor positions, the 3D tongue animation of human participants increased our understanding of tongue

movement during speech. The visual displays of the lingual motion from the clay model and from the participant recordings will be shown.

## **DISCUSSION**

Lingual movement signals acquired by use of the AG500 can be translated into visual representations of lingual movement. Thus, the AG500 EMA system has great potential to be used not only as a research tool to investigate speech motor control, but more importantly as a biofeedback device for numerous populations. Several further obstacles will need to be overcome before this use can be achieved, namely, the acquisition and processing speed for calculating the sensor positions will need to be increased so that those data could be input to the translational programs in a realistic time frame. Currently, the calculation of the sensor positions is extremely lengthy due to the number of such calculations and the manner in which they are processed. In addition, further studies are needed to determine the least number of sensors and their placement on the tongue to be used in the translation program. It is hoped that a technique similar to that which is used in computer graphics for model driven facial animation can be applied, a "master" graphical model of the tongue to which each individual's tongue could be "morphed" to fit. This would enable fewer sensors during recording. Once these limitations are overcome, such visual biofeedback of tongue movement will be assessed in the speech rehabilitation of persons who have suffered various types of brain damage (traumatic brain injury, Parkinson's disease, stroke, etc). This type of visual biofeedback could also be invaluable for those persons who are deaf and do not have access to acoustic biofeedback information when learning to speak. And finally it could be useful to anyone who has ever tried to learn a second language.

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