

Direct Measurement of Vocal Tract Shape - Articulography

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ABSTRACT

An electromagnetic device is presented that allows direct measurements of articulator movements (tongue, jaw, lips and velum) under speech conditions. Compared to X-ray systems or ultrasound scanning this recording technique is non-invasive and affordable. We exploit the fact that the distances of miniature detector coils (on e.g. the tongue) from transmitter coils around the head of a speaker obey the dipolar $1/r^3$ -law for radiated intensity. Possible detector coil tilt is compensated for digitally.

ARTICULOGRAPHY

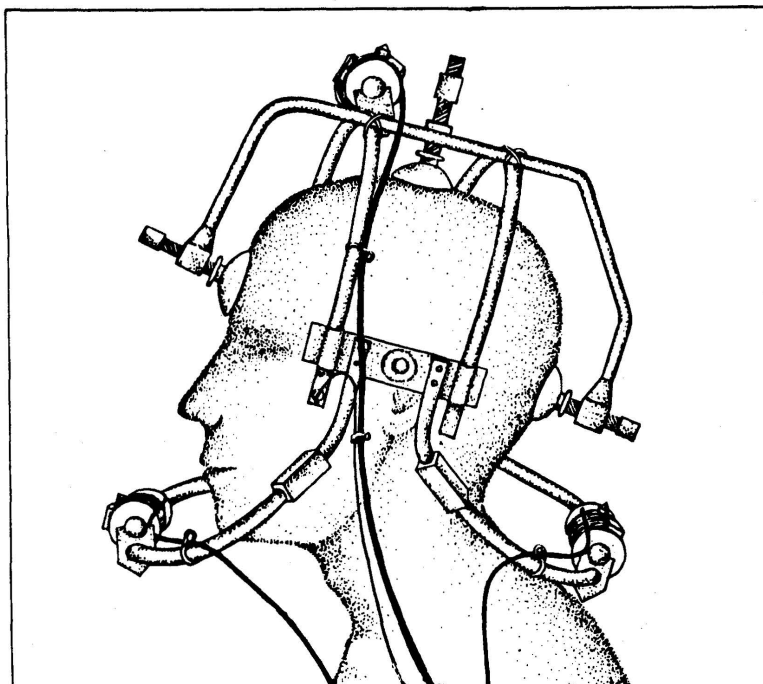


Fig. 1 Electromagnetic articulography. The transmitter coils' radiation is picked up by miniature detector coils attached to the articulators of the speaker. The induced signals allow calculation of the detectors' positions.

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+) supported by Der Bundesminister für Forschung und Technologie

METHOD

Three transmitting coils aligned in parallel around the head of the speaker and radiating at different frequencies in the range of 12 KHz induce a voltage in miniature detector coils (fig.1). These detector coils are attached to the articulators: velum, tongue, jaw and lips. For each detector the induced combination signal is fed into analogue circuitry via thin wires and is separated into its three components - each stemming from one of the transmitters. The transmitter-detector distances are then determined from the dipolar $1/r^3$ -dependence of the signal strength as picked up by a detector at a distance r from a dipole transmitter.

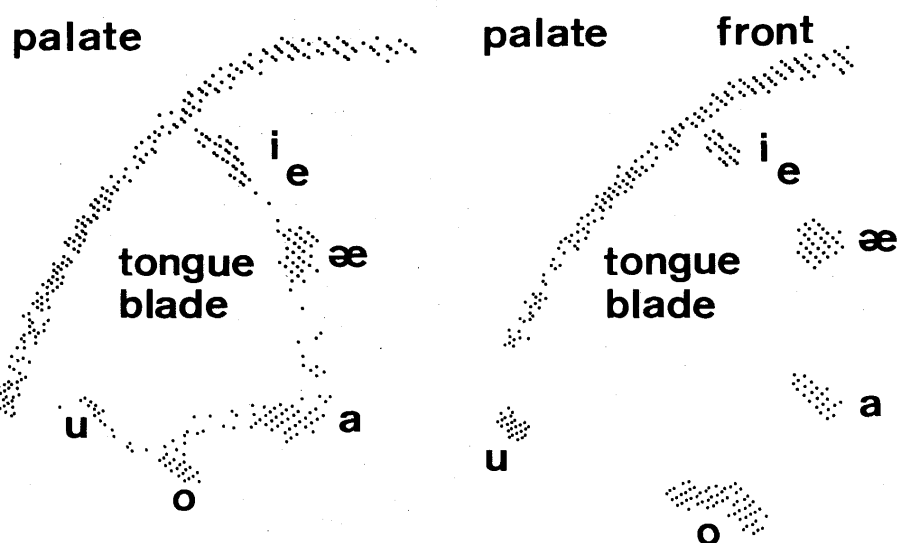


Fig. 2 Trajectories in the mid-sagittal plane. The speaker was instructed to articulate German vowels without interruption (left) and in consecutive trials (right). The detector was attached to the tongue center and thus allows registration of the tongue's movement. The palate contour is recorded by sliding the detector past the palate.

The use of three transmitters for our device is necessary to compensate for unavoidable detector coil tilt with respect to the transmitters' orientation which would otherwise lead to erroneous distance measurements. The independent determination of three transmitter-detector distances allows calculation of the two-dimensional coordinates of the detector in the mid-sagittal plane and the tilt angle between the detector and the three transmitters. The coordinates of each detector are calculated iteratively. Implementation of the algorithm on a TMS 320 processor leads to a mean time of 2.5 msec for the calculation of a detector's position, enabling real time registration of articulator movements (fig. 2). Articulator positions are presently measured to an accuracy of 0.3 mm.

APPLICATIONS

Real time measurements of articulator movements find direct applications in clinical studies and rehabilitation. Presently, we investigate motor speech disorders to identify the pathologic articulator movements responsible for disturbed speech. In a related project changes in tongue and velum movements are recorded in patients who have undergone surgery in the vocal tract area. Phonetic research will gain new insights by connecting the perceived acoustic signal to the underlying physiology of articulator movements (fig.3). As an example, a study on tongue movements for the palatalization of Russian vowels has just been completed.

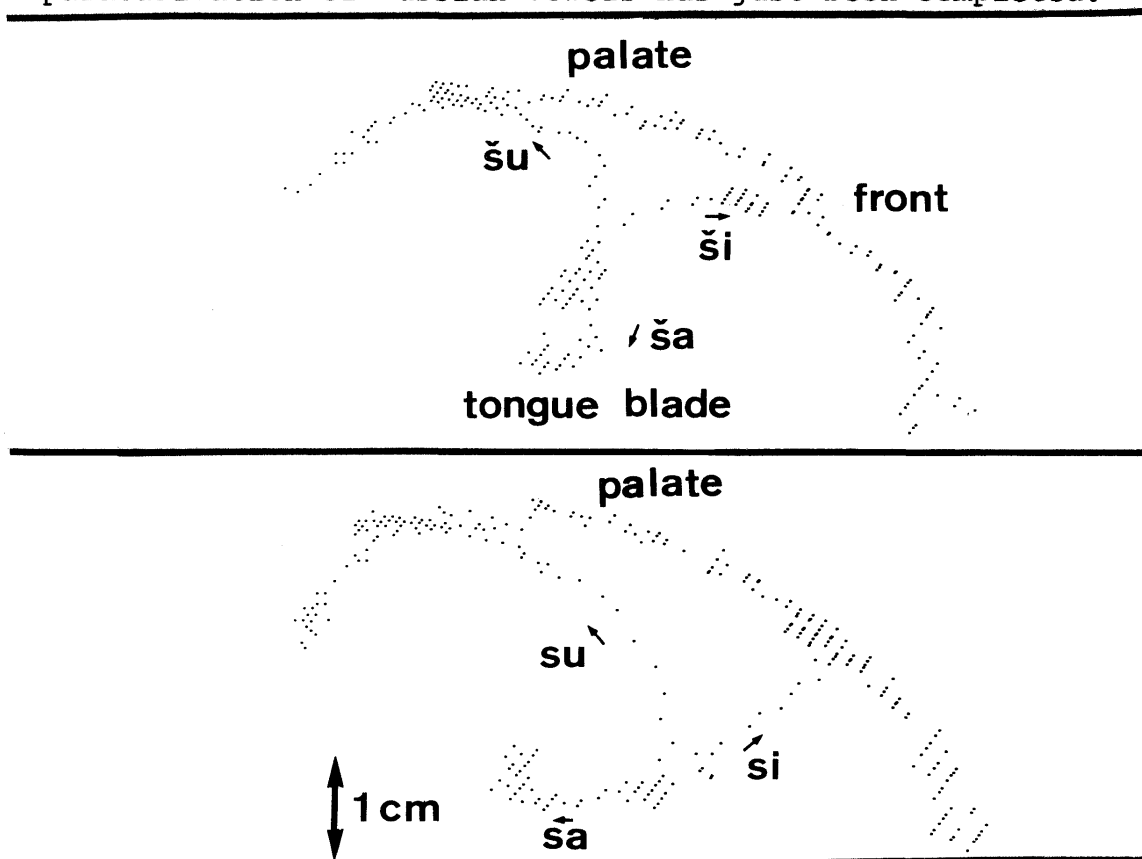


Fig. 3 Relation between perceived speech and articulator positions. The speaker was asked to first produce vowels i,a,u preceded by 'sh' like in 'shut' (top) and then to produce the same vowels preceded by 's' like in 'silver' (bottom). The initial position of the tongue blade as well as the direction of movement are clearly distinct.

Finally, models of the vocal tract connecting the produced sound with vocal tract shape can now be easily tested. Electromagnetic registration is a non-invasive and affordable technique - in contrast to the hitherto used X-ray methods. The new device allows to study the physiological constraints of articulator movements and thus of speech production and should yield efficient descriptions of the speech production process and improve techniques for more natural-sounding synthetic speech.