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Airflow outside the mouth is diagnostic of articulatory activities in the vocal tract, both total volume-velocity and the distribution of particle velocities over the flow-front being useful for this purpose. A system for recording and displaying both these types of information is described. This consists of a matrix of 16 hot-wire anemometer flow sensors, a PDP-4 Digital computer, an X-Y oscilloscope screen in spatial locations corresponding to the locations of the sensors and of sizes corresponding to the flow-velocity at each location, and a control box enabling the operator to select "interactive," "record," and "recall" modes of operation. (See related document ED 016 957.) (Author/DO)

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STUDY OF AIRFLOW OUT OF THE MOUTH DURING SPEECH[1]

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Airflow outside the mouth is diagnostic of articulatory activities in the vocal tract, both total volume-velocity and the distribution of particle velocities over the flow-front being useful for this purpose. A system for recording and displaying both these types of information is described. This consists of a matrix of 16 hot-wire anemometer flow sensors, a PDP-4 Digital computer, an X-Y oscilloscope, a circuit generating circles on the oscilloscope screen in spatial locations corresponding to the locations of the sensors and of sizes corresponding to the flow-velocity at each location, and a control box enabling the operator to select "interactive," "record" and "recall" modes of operation.

In our last Progress Report we presented a survey of work on the visualization and recording of the pattern of airflow just outside the mouth (Lane, et al.,1967). Here we recapitulate briefly the object of this study and present the latest developments.

Once the air used in speech production has flowed out of the mouth it has already done the work of generating sounds and might, in consequence, be regarded as "merely exhaust." As such it might seem of little relevance to the phonetic study of speech. Nevertheless, it still has what may be termed "diagnostic" value.

In the first place, variations in the total volume-velocity of the airflow as a function of time reflect variations in articulatory flow-impedance within the vocal tract, indicating whether a stop, a fricative, a vowel, and so on, has been pronounced. This total flow is what has been studied for nearly a century by means of the phonetic kymograph.

Secondly, the airflow immediately in front of the mouth still retains to some degree a direction and a pattern imposed upon it by the cross-sectional area and the location of the articulatory channels through which it has flowed. In other words, the location of the flow-front, and the distribution and magnitude of particle velocities over this front, add some articulatory information to that given by the variations in total volume-velocity.

The combined information--total flow plus flow-front pattern--which it is the object of this series of developmental studies to record--may be utilizable, through real-time computerized matching of patterns of flow of a student and a model, in a self-instructional device, such as the SAID System (Buiten & Lane, 1965), for teaching pronunciation.

Recent work has brought us nearer to a usable visual display for this purpose, though development is still required particularly in the devising of automatic pattern-matching, and probably in the addition of a velocity-contour type of presentation to the present type of "map" of discrete point-velocities. The following is a brief description of the system in its present stage of development.

The system components are: a) 16 hot-wire anemometer circuits; b) a PDP-4 Digital computer; c) an X-Y oscilloscope; d) a circle generating circuit; and e) an operator's control box.

The hot-wire anemometer uses a fine (.0005 in. diameter) tungsten wire as the air velocity sensor. This wire is heated by passing an electric current through it. Air flowing past the probe wire cools it to a greater or lesser degree according to its velocity and changes its electrical resistance. This change is sensed by the circuit connected to the probe, which generates an output voltage corresponding to the air velocity. These output voltages from the 16 flow circuits are transmitted to the computer.

The PDP-4 is a small digital computer with analog/digital and digital/analog converters; and a relay buffer. The 16 flow circuits are connected to a multiplexed analog input. The computer program reads the 16 flow circuit voltages at regular intervals. The program also computes coordinate values for 16 points on a 4 x 4 matrix, and generates corresponding voltages at two of the computer's analog outputs. These voltages are sent to horizontal and vertical inputs of an X-Y oscilloscope (Tektronix Type 503), causing the spot on the screen to move successively to each of the points on the 4 x 4 matrix, which corresponds to the physical configuration of the probe wires. As the computer causes the spot to move to each of the 16 positions, it simultaneously generates a voltage at another analog output which is sent to the circle generating circuit. This voltage is a function of the air velocity at the corresponding probe position.

The circle generating circuit generates two sine waves, differing in phase by 90 degrees. The amplitudes of the signals are controlled by the voltage coming from the computer. The two sine waves are mixed with the horizontal and vertical voltages presented by the computer to the X-Y oscilloscope. In this way, a circle appears at each point on the 4 x 4 matrix on the oscilloscope screen, the size of the circle being a function of the air velocity at the corresponding probe position.

The system also includes a control box to change the state of the computer program. The computer can operate in an "interactive" mode, initiated by pressing a "reset" button. In this state there appears on the oscilloscope a real time display of airflow at the probes. When the "record" button is pressed, the computer continues in this fashion, but in addition it stores in its memory the status of all 16 probes at successive points in time. After about 2 sec., the computer automatically goes into a "recall" state, where it continuously displays on the oscilloscope the first of the previously stored frames. In addition there is a total flow contour displayed at the bottom of the screen, with a small marker at the extreme left. On the control box there is a "forward-reverse" lever. When this is moved to the "forward" position, the computer advances frame by frame in its memory, displaying the frames on the screen, while the marker on the total flow contour moves to the right, indicating where on the total flow curve the matrix is being displayed. When the lever is returned to its neutral position, this action stops and the current frame is displayed continuously on the screen with the marker on the total flow curve remaining stationary. When the lever is moved to the "reverse" position, the action is reversed and the display moves backwards in memory. Finally, in the recall mode each frame displayed can also represent a moving average of 2 to 20 matrices.

Figure 1 is a general diagram of the system.

Insert Figure 1 about here

Figure 2 shows part of the system. The matrix of hot-wire anemometers is in front of the operator whose left hand is on the control box. The system is in the recall mode, and a velocity matrix with a total flow contour beneath it can be seen on the oscilloscope screen beyond the window of the booth.

Insert Figure 2 about here

Figures 3, 4, 5, and 6 are examples of flow patterns photographed from the oscilloscope screen. In these figures the flow pattern is averaged over two matrices.

Insert Figures 3 & 4 about here

Figures 3 and 4 show two stages in the development of a /p/. In Figure 3, the short vertical marker on the total flow contour indicates the location in time of the matrix displayed above it. In this case, the release of lip-closure for the /p/ is just beginning. In Figure 4 the marker has moved up nearly to the peak flow on release of /p/ and there is a well developed velocity-pattern on the screen.

Insert Figures 5 & 6 about here

Figures 5 and 6 show comparable stages in the development of a /t/. In Figure 5 the marker on the total flow contour is at a point just before release of the alveolar closure and the matrix records no flow. In Figure 6 the marker is at the flow peak after release of /t/ and the matrix indicates the distribution of velocities over the flow front at this time.

Further developments include modifications of the flow-sensing circuits which, among other things, will increase the range of velocity-variation indicated by the size of circles on the screen. At present, the circles reach maximum size at too low a velocity. Flow-pattern discrimination will be greatly increased by this modification. In addition, programs are being developed to provide automatic pattern matching, and other refinements in processing and display of data.

Footnote

[1]The research reported herein was performed in part pursuant to Contract OEC-3-6-061784-0508 with the U. S. Department of Health, Education, and Welfare, Office of Education, under the provisions of P. L. 83-531, Cooperative Research, and the provisions of Title VI, P. L. 85-864, as amended. This research report is one of several which have been submitted to the Office of Education as Studies in language and language behavior, Progress Report VI, February 1, 1968.

Figure Captions

Fig. 1. Diagram of the airflow pattern display system.

Fig. 2. General view of part of the system.

Figs. 3 & 4. Stages in the development of airflow for /p/.

Figs. 5 & 6. Stages in the development of airflow for /t/.

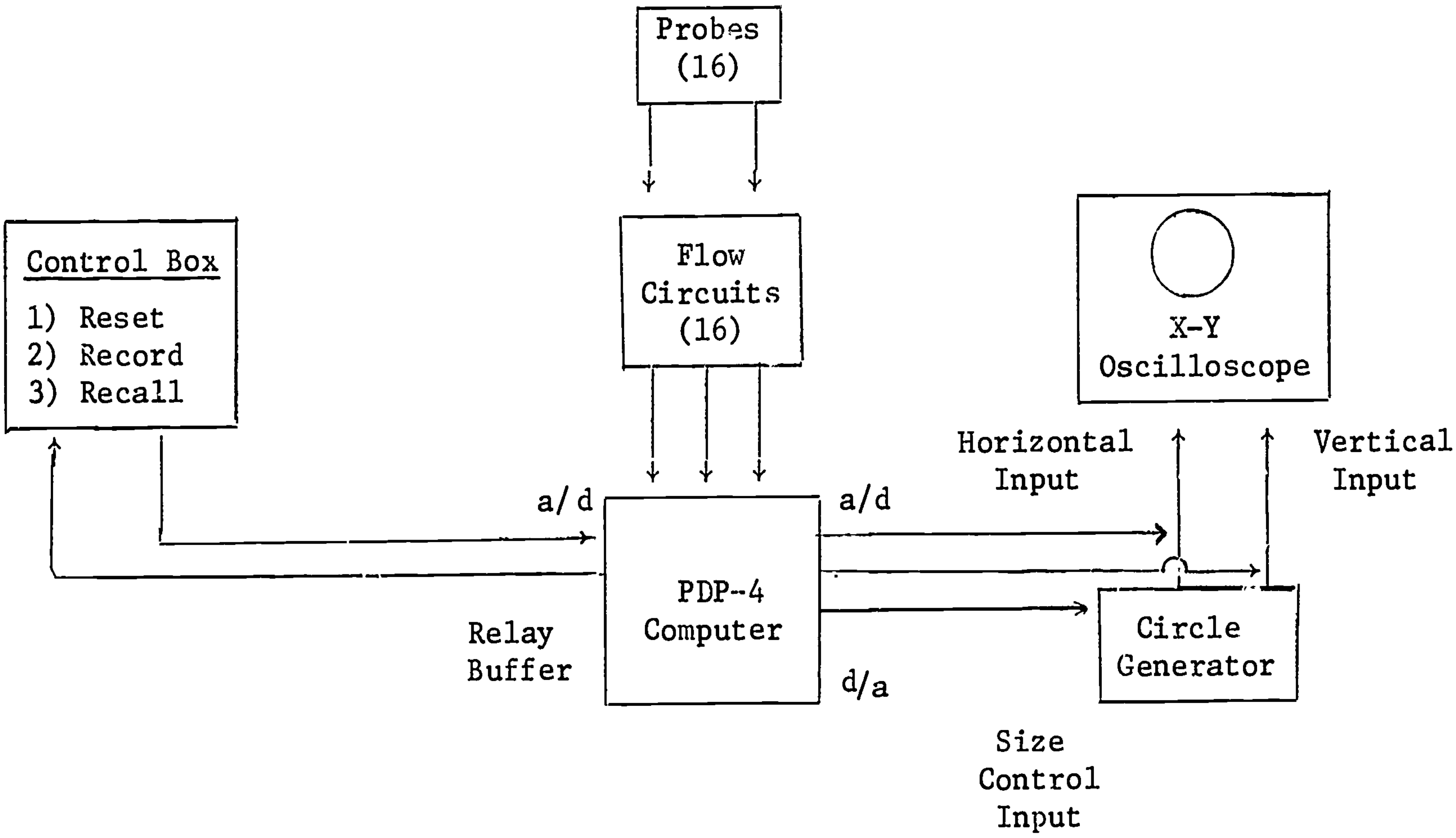

Figure 1

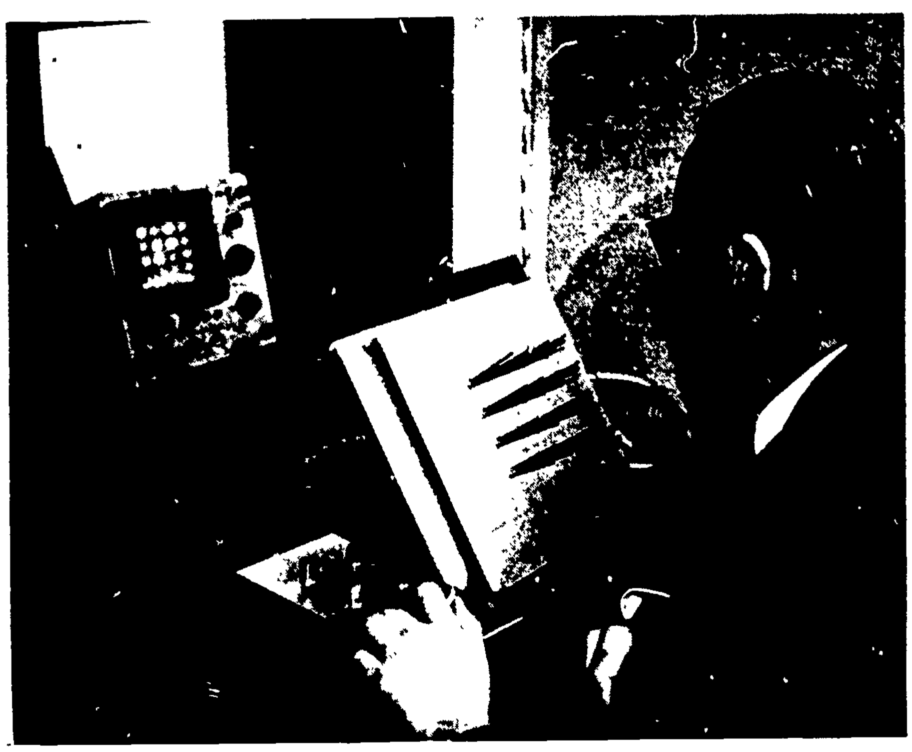

Figure 2

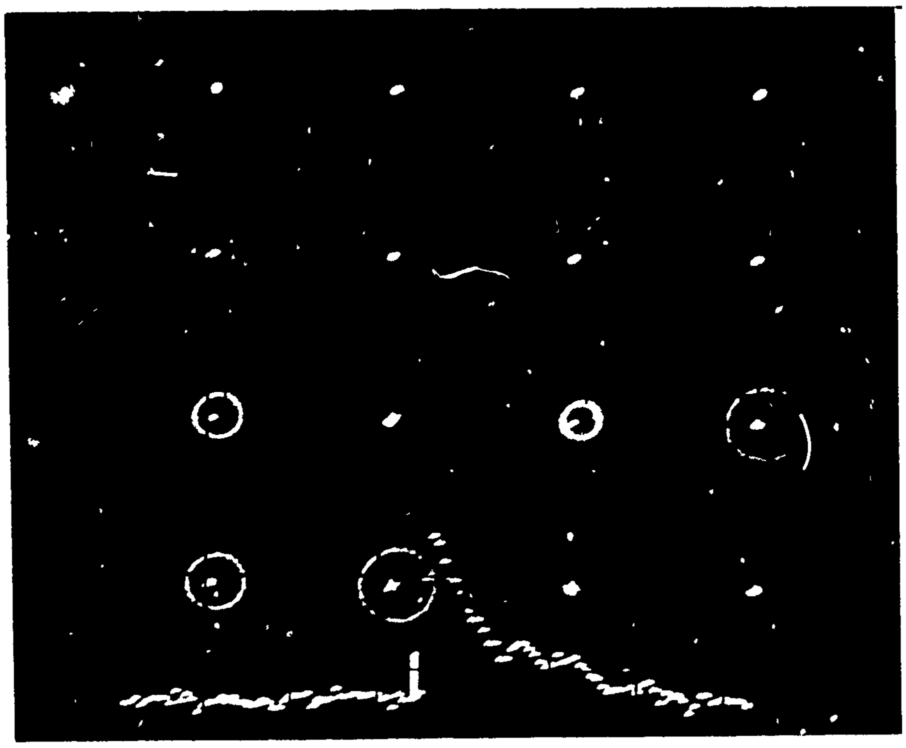

Figure 3

Figure 4

Figure 5

Figure 6