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The optacon

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B. THE OPTACON

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Abstract

Equipment for displaying speech-derived signals on the vibrator matrix of an Optacon is described. The aim is to test if the inherent short-time memory of the display mode used in the Optacon, which is very useful when converting visual signals into tactile for the blind also will facilitate the perception of speech-derived signals converted into tactile for the deaf.

Introduction

The OPTACON (OPTical TActile CONverter) is a reading device for the blind developed at Stanford University, USA (Bliss, 1974) and manufactured by Telesensory Systems Inc.*

The device converts printed images such as letters of the alphabet into tactual images that can be felt and read by the blind. The tactual image is formed by a matrix with 6x24 individually controlled vibrators arranged in a 12x24 mm area suiting the finger tip. The user moves a small camera over the text and the letter seen by the camera appears in tactile analog form on a vibrator matrix which is felt by the left hand index finger. Reading rates of 400 letters per minute have been reported (Hill, 1973). Reading rates around 200 letters per minute seem possible for most subjects to achieve after a relatively short training time. This reading rate is higher than those that have been reported from earlier devices. Experiments show that increased reading rate is obtained when the number of columns in the display is increased, Taenzer (1971).

Experiments with tactual speech transmission have been made at different laboratories since the middle of the 1920's. In the first experiments only one vibrator was used but later the experiments were concentrated on devices where a row of vibrators representing a frequency scale was used, Gault (1924, 1928); Wiener (1949); Kringlebotn (1968). Evaluation experiments with these devices show that deaf subjects can learn to recognize some speech elements by means of a tactual device, Löfgren and Nyqvist (1962); Pickett (1963), but that the amount of information transmitted is not large enough to make the tactual system a useful substitute for hearing.

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The good results with the Optacon reading machine seem to indicate that the way in which the tactual information is transmitted in this device is better matched to the information receiving capacity of the tactual sense. It therefore should be of great interest to evaluate the Optacon matrix as a transmitter of speech-derived signals such as formant frequencies, pitch, intensities etc. In the following an equipment which can control an Optacon, so that it can display speech-derived signals, is described. A computer program for experiments with simulated signals will also be discussed.

Technical description of the control equipment

The Optacon is built so that it can be connected to one or more other Optacons either as a master or as a slave. This option is for teaching purposes. The input/output is arranged in six parallel data lines A-F each corresponding to a column in the vibrator matrix.

The 24 bits of data for one column enter in serial form and are internally distributed to its corresponding row. To complete one frame takes 4 msec which means that each vibrator may be activated once per 4 msec. The activating pulse for a single vibrator has a duration of $4/24 = 160 \mu s$.

The order of activating the rows is that the first 12 bits activate the odd rows and the following 12 activate the even ones. This arrangement makes it possible to display the odd and even rows with different polarity of vibrator movement which lowers the noise level. The output from the Optacon is two clock signals. $\Phi_p$ which is a frame synchronous clock pulse (-7.5 V) with a period of 4 msec and a duty cycle of 160 $\mu s$, and $\Phi_2$ which is a clock pulse (-18 V) synchronous with the scanning of the rows. The period is 160 $\mu s$ and the duty cycle is 5 $\mu s$.

Function

The type of display used in the Optacon is the so-called "flow mode" where patterns seen by the camera enter the matrix on the right side and move to the left in the same way as the test is moving relative the camera.

To get the same type of display with a time-varying speech-derived signal, where the input signal affects only the rightmost column and the
information thereafter is stepped column by column to the left, we need to be able to store a whole frame in a memory. This is achieved by means of six 24-bit shift registers, see Fig. II-B-1. The 24 binary input signals are converted by means of the signal scanner to a signal sequence that is fed into shift register F during the first 4 msec. During the next 4 msec the signals in this shift register are distributed to the 24 vibrators in the rightmost column. At the same time this signal sequence is also transferred into shift register E and a new sequence of input signals is fed into shift register F. During the following sampling interval of 4 msec the signals in shift registers F and E are displayed on the respective vibrator columns and new data are fed into shift register F. In this way the time varying input signals are displayed on the vibrator matrix.

Fig. II-B-2 shows a circuit with six shift registers, which can meet these specifications. Data always have to pass one register before it reaches the Optacon which means that the data are always delayed 4 msec. A delay of 4 msec will not affect the perceived coincidence between visual and tactual stimuli when the device is used as a lipreading aid and can therefore be neglected. As mentioned earlier, the sample time of one column is always 4 msec. One frame is built up of six columns which means that the shortest time window the matrix can cover is 6x4 msec = 24 msec. By keeping the memory in the "recirculated mode" for a time which can be 4 msec multiplied with any integer, the time window of the whole matrix can be made any size in increments of 24 msec. A larger time window of course means a poorer time resolution. The sampling theorem will restrict the highest frequency which theoretically can be displayed to

$$f = \frac{1}{2} \cdot \frac{250}{N} = \frac{125}{N} \text{ Hz}$$

where N is the multiplication factor of the time window. For N=1 the highest frequency will be 125 Hz. A higher N will increase the display time but it will also decrease the highest frequency one can display. It is obvious that the highest frequency of the input parameter to be displayed will affect the optimal sample interval. The length of the tactile short time memory will also be an important parameter when deciding the optimum window width. Fig. II-B-2 also shows an option to enter data into all the six registers in parallel.
pattern moves right-left

vibrator matrix

row nr.
24  o  o  o  o  o  o  o
23  o  o  o  o  o  o  o
22  o  o  o  o  o  o  o
21  o  o  o  o  o  o  o
20  o  o  o  o  o  o  o
19  o  o  o  o  o  o  o
18  o  o  o  o  o  o  o
17  o  o  o  o  o  o  o
16  o  o  o  o  o  o  o
15  o  o  o  o  o  o  o
14  o  o  o  o  o  o  o
13  o  o  o  o  o  o  o
12  o  o  o  o  o  o  o
11  o  o  o  o  o  o  o
10  o  o  o  o  o  o  o
9   o  o  o  o  o  o  o
8   o  o  o  o  o  o  o
7   o  o  o  o  o  o  o
6   o  o  o  o  o  o  o
5   o  o  o  o  o  o  o
4   o  o  o  o  o  o  o
3   o  o  o  o  o  o  o
2   o  o  o  o  o  o  o
1   o  o  o  o  o  o  o

OPTACON

row scanner

Clock

shift register memories

A B C D E F

manual control

input of sampling

speech derived
signal

signal scanner

parameter value

-6 -5 -4 -3 -2 -1 0

sampling interval = n \times 4 ms

Fig. II-B-1.
Fig. II-B-3 shows a circuit to control the memory mode, i.e. if the memory shall recirculate or be open for new data. The monostable is set by the frame sync $\Phi_p$ which has a period of 4 msec. The monostable controls the J and K inputs of the flip flop. A change in the status of the monostable is transferred to the flip flop by the $\Phi_p$ pulse to follow. This means that if the reset time of the monostable is less than 4 msec, the $\Phi_p$ output will always be in the "data enter" mode and if the reset time exceeds 4 msec the $\Phi_p$ output will be in the "recirculate" mode but for the 4 msec immediately following the setting of the monostable when data for a new column is entered.

By controlling the reset time with the potentiometer one can control the time between two adjacent columns or the time resolution of the tactile pattern. Put the other way, one can control the display time or the time window of the tactile pattern to be any multiple of 24 msec.

The display time can also be reduced without affecting of the time resolution by disconnecting of 1-5 columns. The circuit for doing this is shown in Fig. II-B-1. The potentiometer can be set to disable all outputs but output F.

A multiplexer circuit for realizing the 24 inputs corresponding to the matrix rows was also built and is shown in Fig. II-B-4. The counter CD 4024 clocked by $\Phi_2$ and reset by $\Phi_p$ distributes the 24 input channels of 3 CD4051 to one output which can feed the serial input of the memory. The scanning of all inputs takes 4 msec which is about 160 $\mu$s per input. The order of the input channels is, as mentioned before, the 12 odd ones followed by the 12 even. The output is biased to -5V with a 100 k resistor in order to get no activation of the vibrators if its corresponding input is not connected.

**Computer program**

Preliminary experiments have been made with the Optacon display in the described mode. To facilitate controlled experiment with tactile stimuli a computer program has been written (Kjell Elenius) which makes it possible to generate any tactile image.

This is done on the terminal screen where a matrix, 24 segments (corresponding to the rows) high and any number of segments (time axis)
SAMPLING INTERVAL CONTROL

Sampletime $T_{\varphi_p} = 4 \text{ ms}$

Sample interval $T_{\varphi_p}^{-1} = n \times 4 \text{ ms} \ (n \geq 1)$
Max input swing = 10 V
long, is plotted. Those cells in the matrix which correspond to vibrators to be activated are marked. The whole image is then named and placed in an image library.

On-line tests can be performed by the computer which, from a specified library, randomly chooses an image and presents it to the subject. The subjects respond on the terminal keyboard. After testing results are automatically typed out.

References:


