XII. COGNITIVE INFORMATION PROCESSING*

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A. COGNITIVE PROCESSES

1. BILINGUAL FACILITATION OF SHORT-TERM MEMORY

The phenomenon of bilingualism provides an interesting opportunity to study the way information is organized, stored and retrieved – in effect, what a nervous system does to its informational inputs – for with bilingual individuals the information is all within one head. One can present to the fluent bilingual person information in one of his languages and test for it in the other, noting in the meantime how it is maintained, transformed, or degraded. One can also inquire into the nature of the coding processes that human subjects use to define the environment to themselves linguistically: What "unit" is the basis of the information encoded? In some cases, information appears to be tied directly to the words with which it is encoded,[1] in such a fashion that the information varies with particular linguistic forms; but in other cases, the information seems to exist in the subject's head relatively independently of the language used for encoding it.

Consider, for example, the difference between a culturally defined proverb on the one hand, and the laws of physics on the other. Proverbs are notoriously difficult to translate, and in many cases their particular import seems to be tied to their linguistic form. Information of a more universally applicable kind, however, may be more nearly independent of its linguistic form. In such cases, one may believe, it is some property such as a relation or other abstraction that exists in the mind.

Let a human subject see a list of words which he is subsequently required to recall. What processes does he go through to encode the words, store them, and retrieve them subsequently? Some psychologists believe that it is the words themselves that are processed and retained directly; others believe that the words set up some set of associations or images; and others believe still other things. A particular phenomenon relating the availability of items for subsequent recall to their frequency of presentation provided a means for making a test of this question.

The probability of recalling some word from a serially presented list of unconnected

*This work was supported in part by the National Science Foundation (Grant GP-2495), the National Institutes of Health (Grant MH-04737-04), and the National Aeronautics and Space Administration (Grant NsG-496).

words varies with its frequency of occurrence within the list; the more frequent its occurrence, the greater the likelihood of its subsequent recall. In a long list, however, the items heading and ending the list are more frequently recalled than the items from the interior, a serial position effect. But if the items from the first and last 10 positions on the list are excluded from the scoring, the probability of recalling the remaining items is found to increase linearly with an increase in their frequency of presentation: a word presented four times in the list is twice as likely to be recalled as a word presented twice. The question that we were concerned with is whether this facilitory effect of repetition upon recall occurs interlingually. Is the probability of recalling some word presented $\underline{n}$ times on a list the same or different from the probability of recalling it when the word and its translation are each presented $\underline{n}/2$ times to a bilingual subject?

Two kinds of lists were prepared. One, the nontranslated (NT), contained English and French words whose frequency of occurrence varied from one to four in lists 120 items long. In the other, translated lists (T), English-French pairs of words were presented from one to four times each, distributed in random fashion. The subjects observed 10 lists of each kind, one list at a time, and wrote down all of the items from a list they were able to recall immediately after it was terminated.

The principal result is shown in Fig. XII-1, where the proportion of words recalled from the various lists is shown on the vertical axis as a function of the frequency with which items were presented. An abscissa value of $\underline{4}$ means that an English or a French

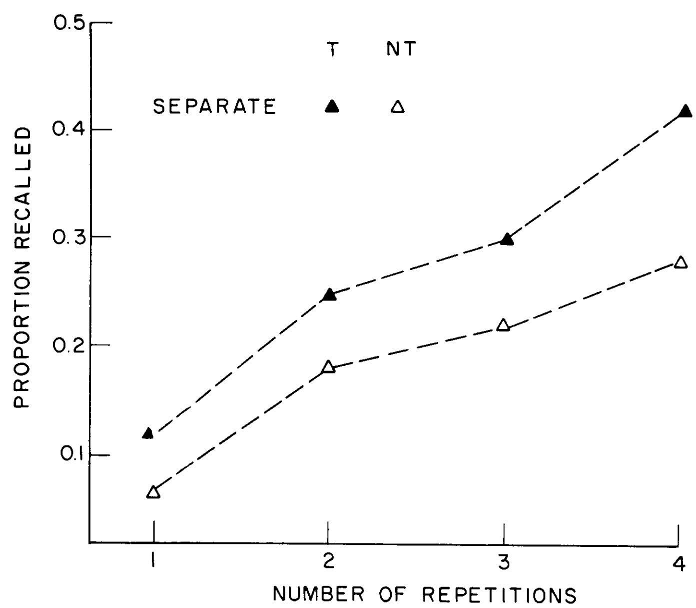

Fig. XII-1. Results of experiment.

word was presented 4 times in the list. For the NT words, these are simple frequencies; for the T words, however, the abscissa means that the word was presented that many times in each of the two languages. The figure averages performance across languages, lists, and subjects. It shows that the probability of recalling some item increases with its frequency of presentation, and that the probability of recalling an item in English, for example, is twice as great when its translation in French also appears in the list as when the item alone appears.

The results can be illustrated more concretely. They indicate that presenting a French-English bilingual with two words, say, wheat and blé, for example, has the same effect upon his recall of either of them as presenting either one twice. One might think from this that the subjects were merely translating the words presented to them, thus supplying themselves with the double stimulation translation provides. This is not a reasonable assumption, however, for the words appeared at the rate of one per second, too fast for this to have occurred. Furthermore, in a control experiment, we found that the subjects did just as well with lists made up of some translated and some non-translated pairs as they did with translated pairs only, and that the false-alarm rate of mistranslation was nearly zero.

The conclusion that we draw from these results is that it is not words themselves that are encoded when a subject is presented a long unconnected list. Rather, their referential property, the "concepts" they represent, are perceived and stored. Words such as blé and wheat are neither visually nor phonetically similar; the fact that presenting either of them facilitates the subsequent recall of the other must be due to their conceptual identity, and it is in terms of such conceptual identities that the words appear to be perceived.

P. A. Kolers

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B. PICTURE PROCESSING

1. TWO-DIMENSIONAL SYNTHESIS OF HIGH SPATIAL FREQUENCIES IN PICTURE PROCESSING*

This research is an extension of the work done by J. W. Pan[1] as suggested by W. F. Schreiber.[2] A block diagram of the proposed system of image transmission is

*Part of this work was carried out with the use of the facilities of the IBM 7094 computer at the Computation Center, M. I. T.

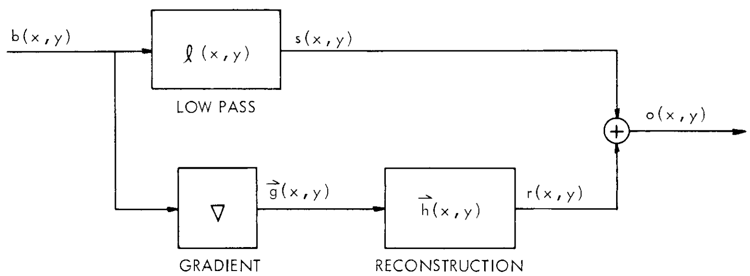

Fig. XII-2. Image transmission system.

shown in Fig. XII-2.

The original picture b(x, y), considered as a signal representing a two-dimensional spatial distribution of brightness, is passed through a lowpass spatial filter l(x, y), and an out-of-focus "lows" signal s(x, y) is produced. The gradient signal of the picture $\vec{g}(x,y)$ is a vector having two components $\frac{\partial b}{\partial x}$ and $\frac{\partial b}{\partial y}$. These are convolved with the reconstruction filter $\vec{h}(x,y)$ to produce the "highs" signal r(x, y). The sum of the "lows" and the "highs" yields the output 0(x, y). Schreiber showed that for a radially symmetric lowpass filter $\ell(r)$, the optimum reconstruction filter is

$$\vec{h}(r) = \frac{1}{2\pi r}\left(1 - 2\pi \int_0^r \ell(r)\, r\, dr\right)\hat{r},$$

where $\hat{r}$ is the unit vector in the r-direction.

For a normalized Gaussian lowpass filter,

$$\ell(r) = \frac{1}{2\pi\sigma^2}\exp\left(-\frac{r^2}{2\sigma^2}\right)$$

$$\vec{h}(r) = \frac{\exp\left(-\frac{r^2}{2\sigma^2}\right)}{2\pi r}\hat{r}.$$

This can be broken down into components

$$h_x = h\cos\theta \qquad h_y = h\sin\theta$$

and convolved with the x and y components of the gradient, respectively.

Since the spread of $\vec{h}$ is less than the spread of $\ell(r)$, an error in transmission will not propagate. Also, an error will be less noticeable because the value of r(x, y) at a given point is a function of the gradient at many surrounding points.

The system shown in Fig. XII-2 was simulated by using the digital television equipment built by our group[3] and the IBM 7094 computer at the M. I. T. Computation Center.

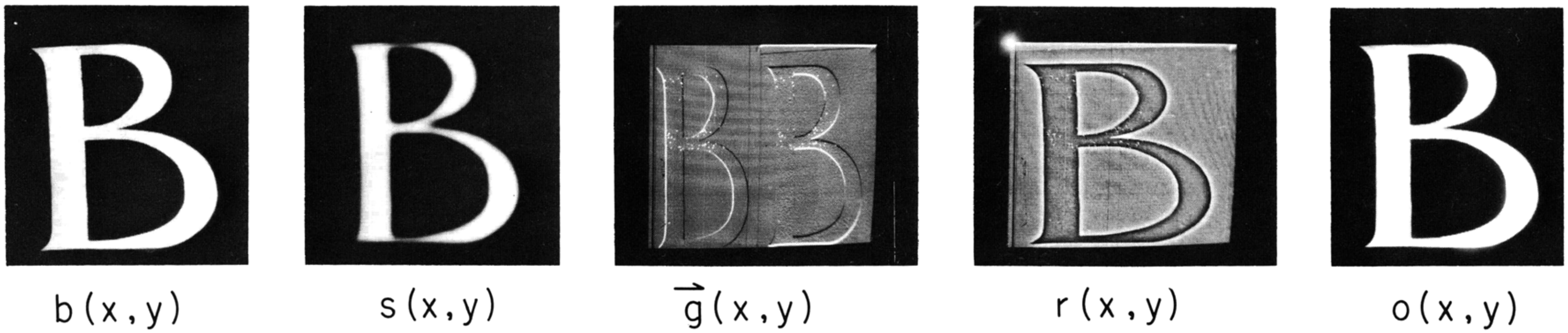

Fig. XII-3. Simulation results.

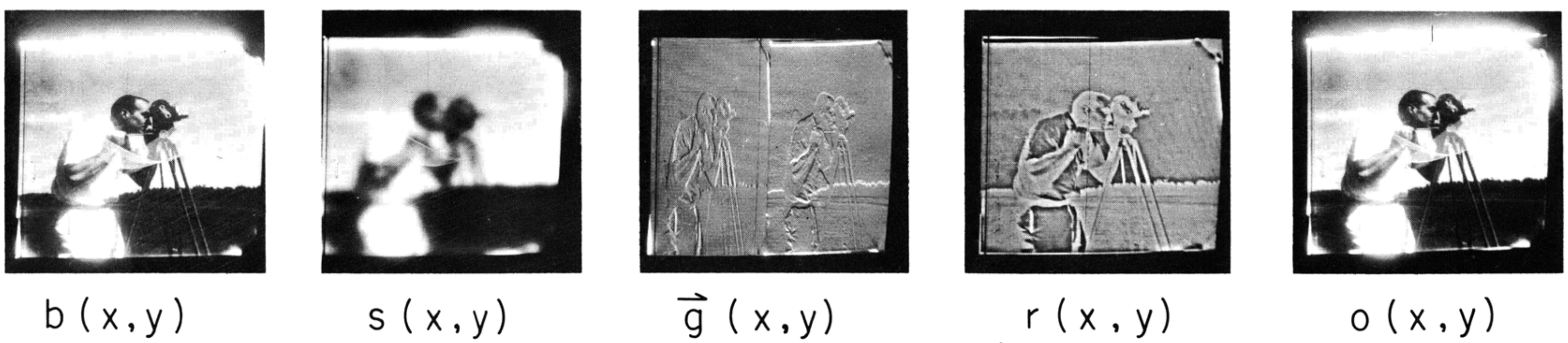

Fig. XII-4. Simulation results.

The results for a Gaussian filter with a sigma of four samples or a spread of approximately 10 percent of the picture height are shown in Figs. XII-3 and XII-4.

In the pictures of $\vec{g}(x,y)$ and $r(x,y)$, zero is represented by the center brightness level, with a negative being darker and a positive being brighter. In $\vec{g}(x,y)$ the horizontal component is on the left and the vertical component on the right.

The quality of the output pictures speaks for the validity of the theory. The research that remains to be completed is to find what nonlinear operations can be performed on $\vec{g}(x,y)$ before transmission so as to reduce the number of bits to be transmitted without seriously affecting the subjective quality of the output picture, noise discrimination, and the optimum choice for the spatial cutoff frequency of $\ell(x,y)$. Since much of the subjectively important gradient information lies along contours in the picture, as is evident in $\vec{g}(x,y)$, fitting conic sections to the contours and then transmitting the parameters of these curves is one way to make use of the two-dimensional nature of the picture.

D. N. Graham

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2. MINIMIZATION OF COINCIDENCE TIME

In this report we solve a simple mathematical problem that has application to space communication. Consider a periodic pulse train with pulse duration τ, period d, and

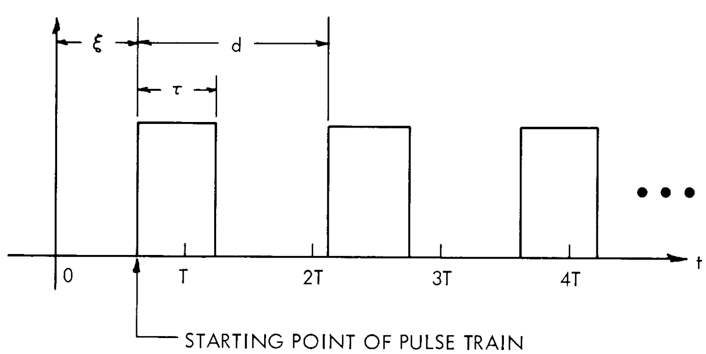

Fig. XII-5.

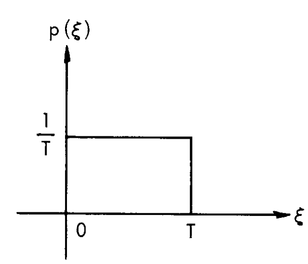

Fig. XII-6.

starting point ξ (Fig. XII-5), where τ and d are constants, and ξ is a random variable uniformly distributed between 0 and some constant T (Fig. XII-6). Assume that $\tau \leqslant T$ and $(n-1)T \leqslant d \leqslant nT$, where n is a positive integer and $n \geqslant 2$. Let N be the smallest integer having the property that the interval $[(N-1)T, NT]$ contains a complete pulse. We use E(N) to denote the expected value of the random variable N. The problem can be stated: Assume that τ, T, and n are fixed. Find values of d, subject to the inequality $(n-1)T \leqslant d \leqslant nT$, which minimize E(N) and $\max_{0\leqslant\xi\leqslant T} N$. We claim that the choice $d = nT - \tau$ will minimize both quantities.

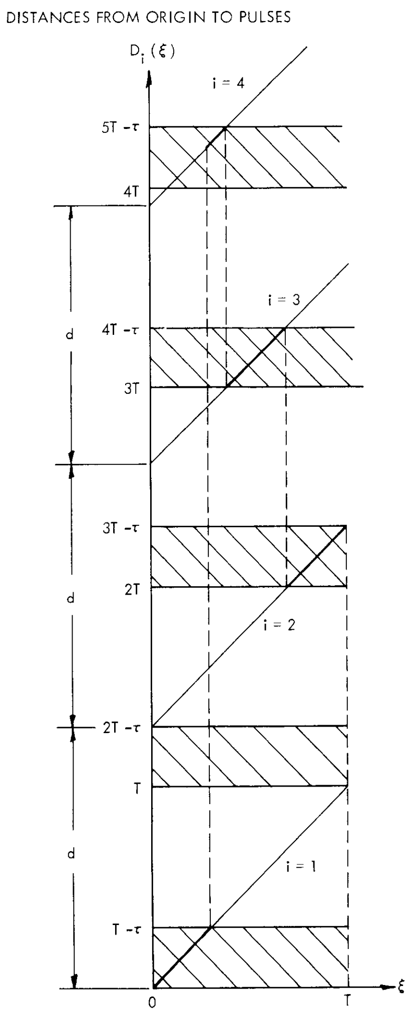

Fig. XII-7.

We shall prove our claim only for the case n = 2; the proof for the general case is similar. We plot the distances from the origin to the leading edges of the pulses against ξ (Fig. XII-7). The distance from the origin to the leading edge of the i^{th} pulse is

$$D_i(\xi) = (i-1)d + \xi; \qquad 0 \leqslant \xi \leqslant T. \tag{1}$$

Let k be a positive integer. Then, for a particular value of ξ the i^{th} pulse lies completely in the interval $[(k-1)T, kT]$, if and only if

$$(k-1)T \leqslant D_i(\xi) \leqslant kT - \tau. \tag{2}$$

We use S_k^i to denote the set of ξ which satisfies (2). Clearly, this set is a closed interval. If S is a union of nonoverlapping intervals containing points in $[0, T]$, we define

$\bar{S}$ = the complement of S with respect to $[0, T]$

and

L(S) = the sum of the lengths of the nonoverlapping intervals in S.

We recall that ξ is uniformly distributed between 0 and T. Therefore, by inspection of Fig. XII-7 it is clear that for any value of d satisfying the inequality $T \leqslant d \leqslant 2T$, we have

$$\Pr\{N=k\} = \frac{L(S_k)}{T}, \tag{3}$$

where k is any positive integer, and

$$S_1 = S_1^1 = T - \tau \tag{4}$$

$$S_2 = S_2^2 \cap \bar{S}_1 = 0 \tag{5}$$

and

$$S_k = S_k^{k-1} \cap \left(\bigcap_{j=1}^{k-1} \bar{S}_j \right); \qquad \text{for } k \geq 3. \tag{6}$$

By definition,

$$E(N) = \sum_{k=1}^{\infty} k \cdot \Pr\{N=k\}. \tag{7}$$

For any d satisfying the inequality $T \leq d \leq 2T$,

$$\Pr\{N=1\} = \frac{T-\tau}{T} \tag{8}$$

$$\Pr\{N=2\} = 0 \tag{9}$$

and

$$\Pr\{N=k\} = \frac{L(S_k)}{T} \leq \frac{L\left(S_k^{k-1}\right)}{T} \leq \frac{T-\tau}{T}; \qquad \text{for } k \geq 3. \tag{10}$$

Also, obviously,

$$\sum_{k=1}^{\infty} \Pr\{N=k\} = 1. \tag{11}$$

We want to minimize (7) under the conditions (8)-(11). In Fig. XII-7 we have used $d = 2T - \tau$. For this choice of d, we have

$$\Pr\{N=k\} = \begin{cases} \dfrac{T-\tau}{T}, & \text{for } 3 \leq k \leq \left[\dfrac{T}{T-\tau}\right] + 1 \\ 1 - \left[\dfrac{T}{T-\tau}\right] \dfrac{T-\tau}{T} < \dfrac{T-\tau}{T}, & \text{for } k = \left[\dfrac{T}{T-\tau}\right] + 2 \\ 0, & \text{for } k \geq \left[\dfrac{T}{T-\tau}\right] + 3 \end{cases} \tag{12}$$

where $\left[\frac{T}{T-\tau}\right]$ = the largest integer in $\frac{T}{T-\tau}$. It should be clear that this set of probabilities when substituted in (7) yields the desired minimum. And

$$\min_{T \leq d \leq 2T} E(N) = \frac{T-\tau}{T} \left(1 + \left\{3+4+\ldots+\left(\left[\frac{T}{T-\tau}\right]+1\right)\right\}\right) + \left(\left[\frac{T}{T-\tau}\right]+2\right)\left(1 - \left[\frac{T}{T-\tau}\right]\frac{T-\tau}{T}\right) \tag{13}$$

Also, for this particular choice of $d = 2T - \tau$, we have

$$\max_{0\leq\xi\leq T} N = \begin{cases} \left[\frac{T}{T-\tau}\right] + 1, & \text{if } \frac{T}{T-\tau} = \text{integer} \\ \left[\frac{T}{T-\tau}\right] + 2, & \text{if } \frac{T}{T-\tau} \neq \text{integer} \end{cases}$$

For $d = 2T - \tau$ the probabilities $\Pr\{N=k\}$, $k \leq \left[\frac{T}{T-\tau}\right] + 1$ have attained their largest possible values; hence, it follows that no matter how we vary d, the quantity $\max\limits_{0\leq\xi\leq T} N$ can never be made less than (14).

Similar reasoning will establish that, of all values of d satisfying the inequality $(n-1)T \leq d \leq nT$, the choice $d = nT - \tau$ minimizes both $E(N)$ and $\max\limits_{0\leq\xi\leq T} N$. Thus

$$\min_{(n-1)T\leq d\leq nT} E(N) = \frac{T-\tau}{T}\left(1+(n-1)\left\{3+4+\ldots+\left(\left[\frac{T}{T-\tau}\right]+1\right)\right\}\right) + (n-1)\left(\left[\frac{T}{T-\tau}\right]+2\right) \times\left(1-\left[\frac{T}{T-\tau}\right]\frac{T-\tau}{T}\right) \tag{15}$$

and

$$\min_{(n-1)T\leq d\leq nT}\left\{\max_{0\leq\xi\leq T} N\right\} = \begin{cases} (n-1)\left[\frac{T}{T-\tau}\right] + 1, & \text{if } \frac{T}{T-\tau} = \text{integer} \\ (n-2)\left(\left[\frac{T}{T-\tau}\right]+1\right) + 1, & \text{if } \frac{T}{T-\tau} \neq \text{integer.} \end{cases}$$

T. S. Huang

3. A PROPERTY OF R, ±C NETWORKS

It is well known that if $Z(s)$ is the driving-point impedance of an RC network, then $\operatorname{Re} Z(jw)$ is monotone nonincreasing for positive w. As far as we are aware, nowhere has it been mentioned that $|Z(jw)|$ has the same property. In fact, it can be easily shown that the magnitude of the driving-point impedance of an R, ±C network is monotone decreasing for positive w. This property follows readily from the following lemma which has been proved by Bello[1] and by Kinariwala[2].

LEMMA. If $Z(s)$ is the driving-point impedance of an R, ±C network, then the poles and zeros of $sZ(s)$ are simple and alternating on the real axis.

THEOREM 1. If $Z(s)$ is the driving-point impedance of an R, ±C network, then $|Z(jw)|$ is monotone decreasing for positive w, unless $Z(s)$ is a constant.

PROOF. From the lemma, we know that the pole-zero plot of $Z(s)$ has the general appearance of Fig. XII-8. Therefore we can always express $Z(s)$ as a product, each factor of which contains one pole and one zero with the pole nearer to the j-axis than the zero which may be at infinity. It can be shown that for $s=jw$, the magnitude of each such

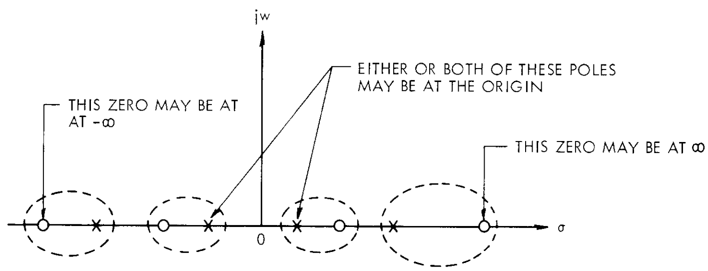

Fig. XII-8. Pole-zero plot of an R, ±C driving-point impedance.

factor is a monotone decreasing function of w for positive w; hence, the same is true of Z(s). Q. E. D.

Similar arguments will establish the following theorem.

THEOREM 2. If Z(s) is the driving-point impedance of an R, ±L network, then |Z(jw)| is monotone increasing for positive w, unless Z(s) is a constant.

T. S. Huang

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C. SENSORY AIDS

1. TWO-DIMENSIONAL ACOUSTIC PATTERN PRESENTATION

This report summarizes work that has been discussed in more detail in the author's Sc. D. thesis. The thesis was concerned with the design, construction, and evaluation of a device for displaying acoustically the two-dimensional motion of a point in a plane.

The input to the display is a pencil-like probe that is movable on a square writing surface. The output, presented to the subject through earphones, sounds like a tone localized in space. The horizontal coordinate of the probe governs the apparent left-right position of the tone, and the vertical coordinate governs the pitch of the tone. A block diagram of the system is shown in Fig. XII-9.

Since broad-spectrum sounds such as noise can be more precisely localized than pure tones, pulse trains with low repetition rates and narrow pulses are used in the display. Such a "comb" signal has strong harmonics throughout the audible range.

The pitch of the output is varied by varying the pulse repetition rate. Equal vertical probe motions produce equal changes in pitch along the musical equal-tempered scale. The pitch range is two octaves from 100 cps to 400 cps. The choice of 24 semitones was influenced by a desire to keep the vertical and horizontal resolutions approximately

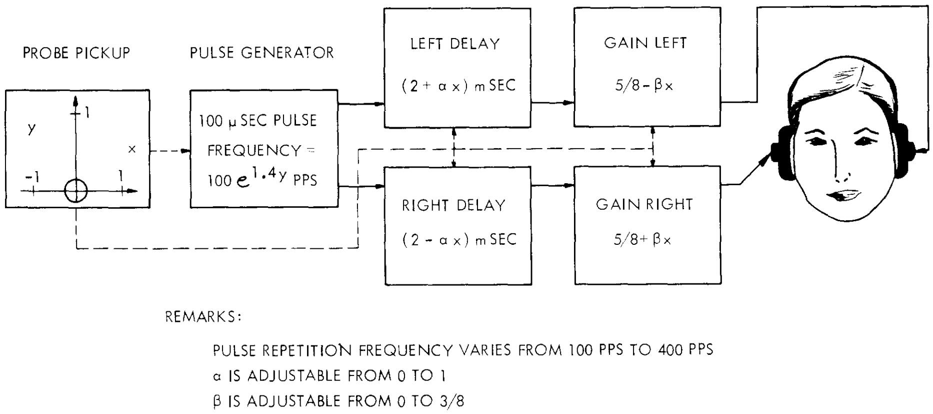

Fig. XII-9. System diagram.

equal. At frequencies lower than 100 cps it is difficult to follow fast motions.

In order to take advantage of both of the mechanisms that humans use for localization, the display employs both delay and amplitude modulation of the two earphone signals.

For pure tones of equal amplitude, relative delay produces a nearly linear change in angular position until the delay reaches the Hornbostel-Wertheimer constant, k. For larger delays the apparent source continues moving around the head, but also moves away. Delays in excess of 2k give the effect of two sources, one in each ear. The constant k depends on loudness and varies from subject to subject, but it is usually between 0.5 msec and 1 msec. Although these data were obtained with pure tones, I thought it reasonable to assume that the effects of delay on pulse trains would be similar. Thus I made the relative delay of the pulse trains to the two ears vary linearly with probe horizontal position. The maximum delay is 2 msec.

Not much is known about the effect of relative amplitude variations on the apparent position of complex sounds. Measurements in the meatus show, however, that relative intensities for real sound sources at various angles and frequencies do not exceed 10-15 db. The display produces a current ratio of 4 (or an intensity ratio of 12 db) when the probe is in an extreme horizontal position. As can be seen in Fig. XII-9 amplitude of the output pulse train is linear with horizontal position. Although this produces an apparent dip in loudness in the center, it was chosen for convenience of instrumentation and for lack of any better alternative.

The earphones are enclosed in baffles that keep external noise from disturbing the subject.

Experiments were designed to investigate the subject's ability to follow small motions, to follow fast motions, to make absolute judgments of position, and to read handwritten letters. A short description which is designed to give the flavor of the experiments that were performed and to indicate their results will be presented here.

In one experiment the experimenter moved the probe from point to point along a grid drawn on the input board. The subject was asked to track the motion of the probe with a pencil on an identical grid. Naturally, the subject could not see the experimenter's motions. Grids of varying degrees of fineness were employed.

In a second experiment the probe traced out circles, and the subject was requested to determine whether the circles were clockwise or counterclockwise. The circles varied in size and position in the writing plane. The velocity of the probe motion was also varied.

In a third experiment the probe, originally in the center of the square writing surface, jumped discontinuously to a new position. The subject indicated where he thought this new position was.

The last experiments involved handwritten letters. The experimenter wrote a single script letter with the probe. The subject tried to guess what it was. Parameters of interest were speed and accuracy.

The results of the experiments can be roughly summarized as follows:

1. The smallest resolvable detail is approximately 1/16 of the side of the writing area.

2. Absolute judgments of position are, at best, accurate within 1/8 of the side of the writing area.

3. Motion with "bandwidth" in excess of 3 cps cannot be followed.

4. Handwritten letters can be read with high accuracy up to 20 letters per minute.

5. The coding is so natural that with no training subjects can read up to 3 letters per minute with fair accuracy. (Eight hours of practice are required to reach the 20 letter per minute level.)

6. If only the vertical component of the letters is transmitted, the error rate does not increase greatly.

W. L. Black

2. TIME EXPANSION OF ULTRASONIC ECHOES AS A DISPLAY METHOD IN ECHOLOCATION

1. Introduction

A useful mobility aid for the blind should provide at least three types of information. It should indicate the presence of obstacles in the traveler's path, locate these obstacles, and identify them. Statements of blind individuals indicate that, although fear of injury from collisions or falls overshadows all else, the major difficulty in foot travel is in maintaining general orientation in walking a straight line and in finding and identifying familiar objects.[1] Many mobility-aid devices constructed in the past, while detecting and locating obstacles, have failed to provide useful identification information, or have provided it at a very slow rate.

Several mobility-aid devices have been constructed that emit ultrasonic sound energy and detect returning echoes. These devices have been able to detect most obstacles that are of interest to a blind traveler (with the very important exception of a step-down) and to provide useful obstacle location information. These devices, however, have given only minimal object-identity information to the user. A display that retains the proved detection and range capabilities of previous ultrasonic mobility aids while giving obstacle-identity information is needed.

Since ultrasonic sound is inaudible, the information provided by ultrasonic echoes must be processed in some manner before it can be displayed to a human observer. A possible display method is to record the ultrasonic echoes and then have an observer listen to the time expansion of the recording. Experiments have been performed that explore the object-identity capabilities of this display method.[2]

2. Experiments

An acoustic radiator that produced a 1-msec, 40-kc/sec sinusoidal pulse was used as an ultrasonic sound source in this experiment. Preliminary work by the author had indicated that the time expansion of this type of signal might provide useful object-identity information. The echoes produced by the sound source from 4 objects were recorded on magnetic tape. It was felt that four was a number of echoes that subjects could be expected to remember after a very short learning period. The objects chosen were a bush, a stool, a person, and a wastepaper basket. These objects are items that a blind person may wish to identify for purposes of orientation and convenience. In this sense they are practical objects. Also, the objects have rather different geometric outlines and a useful device for object-identity purposes would certainly be expected to distinguish among them.

A recording for each object was made of the echo produced when the object was 4 ft from the sound source and the sound source axis was pointed directly at the object. Two subjects with sight listened to a time expansion of these echoes. A time-expansion factor of 64 was used because preliminary work by the experimenter had indicated that this ratio would be an interesting one to investigate. A higher factor seemed to draw out the echoes excessively, and lower factors did not seem to give as much character to the echoes. The subjects were told the name of an object and then heard its echo played fifteen times. This was done for each object and the sequence of four was repeated twice. The subjects were then given a series of 20 trials in which one of the 4 echoes was heard 5 times during a trial.

The use of the proposed echo-identity scheme will be considerably complicated in practice by the facts that all obstacles will not be 4 ft away and that an obstacle may be approached from a variety of angles. In order to find out whether a person might be able an object under varying circumstances, an experiment was performed by using echoes that had been recorded under different conditions of source-object distance and orientation than those used in the preceding experiment. Eleven echoes were used, and 22 trials were given to the subjects. The echoes appeared in two random sequences of 11 each, so that each echo appeared once within a sequence. The subjects were asked to identify the object producing the echo on each trial by comparing what they heard with the four "standard" echoes of the first test. The subjects' combined score was 64 per cent correct. Considering the subjects' lack of training and the artificial nature of the tests, this result is most encouraging. It suggests that the proposed display method may indeed be a useful way to give obstacle-identity information to a blind traveler.

Tests of the kind just described were also performed with expansion factors of 32, 16, and 8. The factor of 32 gave scores comparable to those obtained with a factor of 64, while factors of 16 and 8 gave scores that were little better than would be expected from guessing. The last two rates may require a longer period of learning than the higher rates.

J. A. Rupf

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3. COMPUTER-AIDED SIMULATION OF A MOBILITY AID

For echolocation the short wavelengths of ultrasonic sound offer considerable advantages over the relatively long wavelengths of audible sound. Ultrasonic echoes, however, require processing before a person can use the information that they provide. A possible display method involves recording and subsequent time expansion of the echoes.

The TX-0 computer has been used to control the emission of 40-kc/sec, 1-msec pulses from an acoustic radiator, as will as to accomplish the time expansion of the received echoes. (See Fig. XII-10.) An external pulse from the computer triggered a sound source and started an analog-to-digital converter that sampled the source pulse and returning echoes at a rate of 33 kc/sec. The pulse also gated the sampled data into the live register of the computer. A sampling rate of 33 kc/sec was achieved by using only the six most significant bits of the analog-to-digital converter and poking 3 samples into an 18-bit TX-0 word. The computer then gated the sampled data to a digital-to-analog converter at a rate of 2.1 kc/sec for 0.5 second. This signal was then amplified and fed

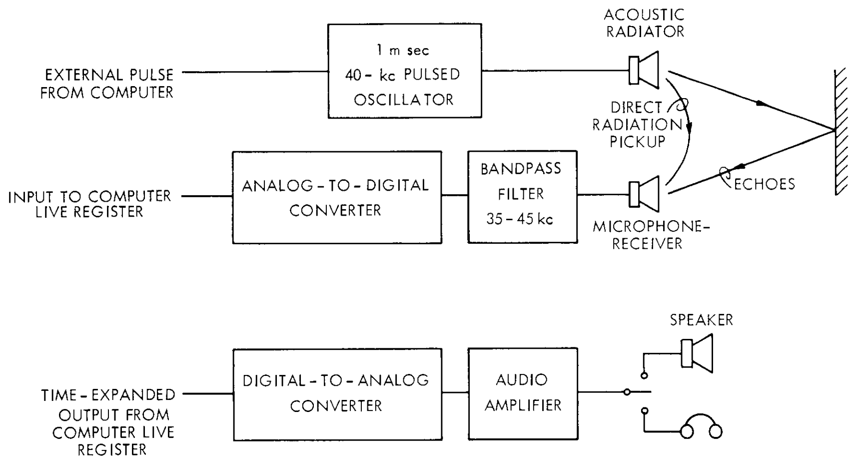

Fig. XII-10. Block diagram of the system.

to a speaker, or to earphones. After completion of the read-out, the cycle was automatically repeated by the computer. Although the sampling rate was only 0.8 sample per carrier cycle, it was sufficient to detect and store an indication of the presence and position of echoes.

The time delay between the onset of the sound source and the returned echo was lengthened by a factor of 16. A subject could then interpret this time delay as the distance to the nearest obstacle. Preliminary experiments indicated that this method of presentation of range information can be easily interpreted by a subject who has had a small amount of training.

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4. ELECTROMECHANICAL PATTERN SIMULATOR

A device that is capable of representing patterns by means of protruding pins (probes), has been designed and tested. The chief advantage of this device lies in the fact that a large number of probes can be controlled independently by a feasible number of electrical inputs. For example, a square array of probes, 100×100, could be controlled by 400 electrical inputs. This is in contrast to a device in which each probe is operated by a single solenoid. The number of inputs needed in this case would be 10,000.

This economy of inputs is achieved by a control process that is similar to the procedure used for "setting" cores in a core memory. Principal components of this control scheme are ferromagnetic iron plates, around which coils are wound in crisscross fashion. A plate for a four-probe model is shown in Fig. XII-11, with the position of the probes and the coils indicated.

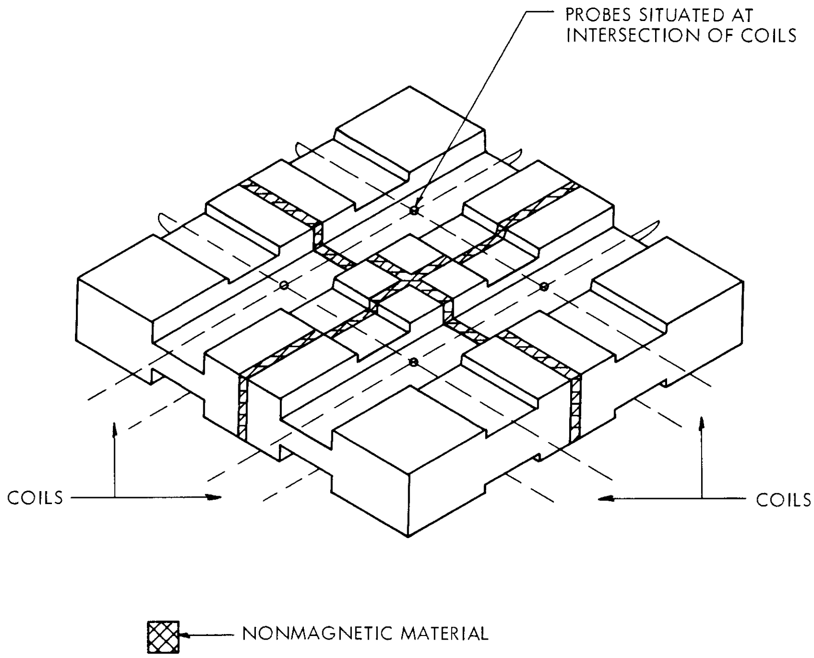

Fig. XII-11. Top (or bottom) plate.

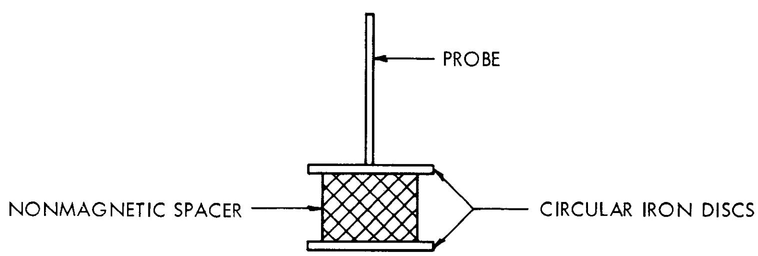

Fig. XII-12. Disc assembly.

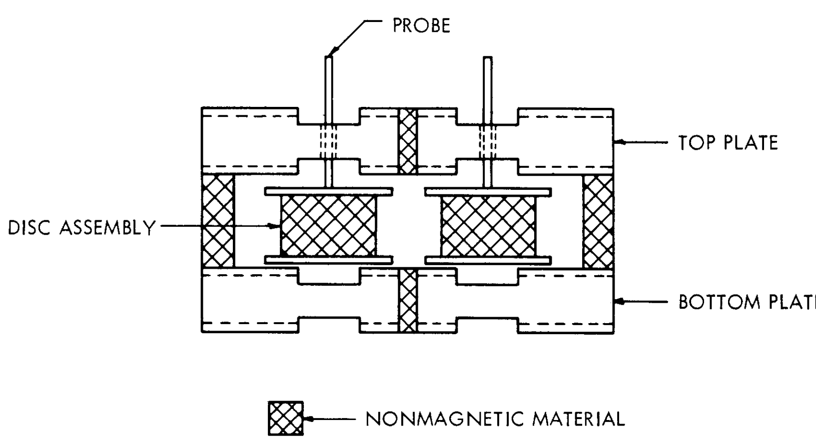

Fig. XII-13. Side view of the assembled device.

The probes are attached to two circular iron discs separated by a nonmagnetic spacer. This is shown in Fig. XII-12.

A side view showing the various parts as they fit together is shown in Fig. XII-13.

When a particular pattern is being utilized, all coils on both the top and bottom plates are excited. Under these conditions, magnetic force is exerted upon a disc assembly by both top and bottom plates. The plate that is closer to the disc assembly will attract it more, however, and hence the position of the disc assembly is bistable.

To change the position of a disc assembly, appropriate coils are de-energized in the appropriate plates. If a disc assembly that is down is to be raised, the excitation upon both of the intersecting coils on the bottom plate corresponding to the probe is removed, and the attraction of the upper plate will draw the disc assembly up. Lowering of a pin involves the inverse of this process. A disc assembly will only react when both of the coils at its intersection are rendered unexcited. If only one coil at an intersection is rendered unexcited, the mmf of the other coil will be sufficient to hold the disc assembly in place. Thus, independent control of each pin can be achieved.

Characteristics and design considerations of this device are dealt with in the Master's thesis upon which this report is based.[1]

R. A. Murphy

References

1. R. A. Murphy, An Electromechanical Pattern Simulator, S. M. Thesis, Department of Electrical Engineering, M. I. T., September 1964.

5. PICTURE BRAILLER

An electromechanical device, the picture Brailler, which in conjunction with an X-Y recorder, is capable of reproducing line drawings in Braille, has been designed, developed, and evaluated. The device is intended to produce pictures of variable size on a standard 11×11 inch Braille sheet. A Braille picture is a representation by a pattern of dots of an ordinary picture. The motions of the device are discrete, and a grid of 100×100 (9 dots per inch) is obtained on the Braille sheet. Scale reproductions (either enlarged or diminished) of line drawings are possible; in addition, the aspect ratio of the picture can be altered.

This is believed to be the first attempt at mechanized reproduction of ordinary pictures in Braille, which had hitherto been laboriously done by hand. This opens up the possibility, aside from the obvious convenience in producing Braille pictures, of further experiments in pattern recognition for blind subjects.

In principle of operation, the picture Brailler is rather similar to the IBM electric typewriter. A rotatable drum, 10 inches long and 5 inches in diameter, mounted on

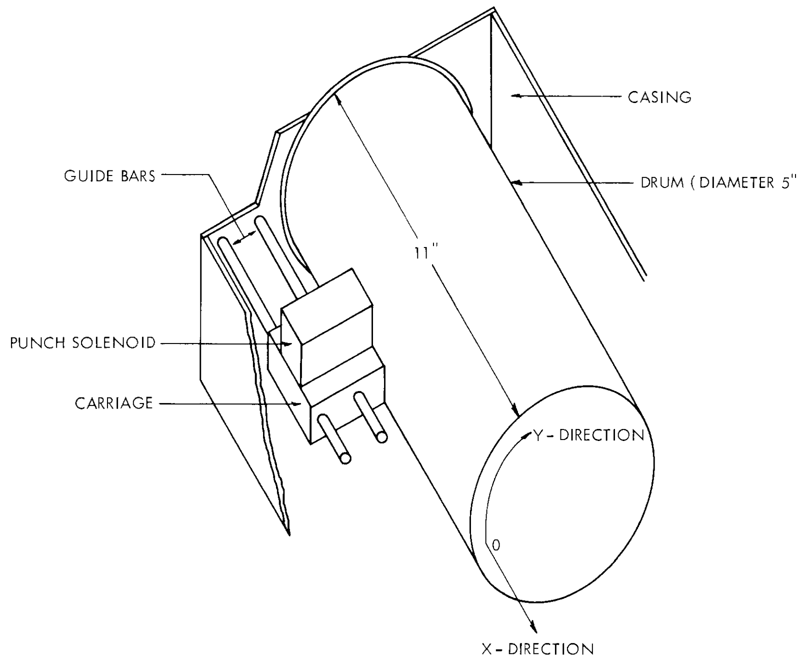

Fig. XII-14. Picture Brailler – mechanical transport and punch.

ball bearings and connected by worm gears to a Digimotor (trade name for stepping motors manufactured by Ledex Corporation), serves as a roller to hold the Braille sheet on which the embossed copy is to be made (Fig. XII-14). The drum is covered with a resilient rubber sheet. A carriage on which a solenoid is mounted slides along two guide bars in front of the drum and serves as the type head. By energizing the solenoid, a raised impression (dot) can be made on the Braille sheet. Hence by suitably positioning the carriage and rotating the drum, a meaningful pattern of dots can be produced on the Braille sheet by energizing the solenoid, thus constituting a picture. The carriage is also driven, through gears, by stepping motors so that all rotational motions of the drum and translational motions (of the solenoid) are essentially discrete in nature.

Potentiometers are attached to the drum and carriage drives. Voltage outputs of these potentiometers are applied to the pen and arm inputs of an X-Y recorder. The pen of the recorder has been replaced by a phototransistor and light source. The output of this light sensor then determines whether or not a dot is to be embossed.

Appropriate digital electronic equipment and a control panel are provided to enable manual adjustment of magnification of the image that is to be copied and the automatic production of the Braille picture.

A demonstration of this device was held at a conference of teachers of the blind at Perkins Institute for the Blind at Watertown, Massachusetts, in June 1964.

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6. ON-LINE BRAILLE CELL FOR THE TX-0 COMPUTER

The Braille cell was developed to establish on-line communication between a blind operator and the TX-0 computer. The cell consists of a series of 6 buffer flip-flops, into which a selected portion of the live register is gated. These flip-flops, through solenoid drivers, control 6 solenoids that raise the pins in a single Braille cell. These pins remain up until the reader depresses a switch located under his thumb. The reset switch clears the cell by resetting all of the buffer flip-flops and providing a voltage level that the computer can detect.

A test program was written for the TX-0 computer which converted flexowriter input from the on-line flexowriter into a modified grade I Braille. If any key on the flexowriter was depressed, its Braille code was immediately presented by the Braille cell until the cell was manually reset. The program detected the reset level and waited for another character to be typed. Also, typing a backspace transferred control to a storage routine, thereby allowing a typist to store up to 8000 flexowriter characters in memory. Pressing the tab key read out these characters to the Braille cell in the same order as they were typed in. The flow of Braille information to the blind user is limited only by his reading speed and the time he requires to push the reset button. Tests have been carried out that indicate that the reading speed can be as high as 4 characters/second without appreciable practice.

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