Some comments on Character Recognition

By E. A. Newman

There is a wide interest, nowadays, both in automatic mechanical language translation and in automatic character recognition. From a scientific point of view both are fascinating subjects, but neither—to the practical man—is an end in itself Both are used as an interpreter to enable several units in a system to communicate where otherwise they could not. Interpreters are redundant to the real task in hand, and, in common with anything else, are liable to error—hence they are things to be avoided whenever possible. In the field of human communication we understand this clearly enough. When it is essential to link together people of differing tongues, as it often is, we use interpreters, but only in most exceptional circumstances would we create a team of men to do a task from a group of men no one of whom knows the language of any other. Admittedly, we could employ a group of interpreters to make communication possible, but what a silly thing that would be to do! Yet we will cheerfully consider constructing a team from a hotch-potch of men and machines, and then bludgeon our way out of the ensuing chaos by using a series of expensive interpreting machines.

Need for Interpreting Machines

This is not to say, however, that interpreting machines should never be used. There are, indeed, many situations involving the use of groups of machines, particularly where human intervention is needed, where the use of interpretation is essential.

Consider a system such as is illustrated in Fig. 1, consisting both of men, denoted by arabic characters A, B, etc., and machines, denoted by Greek characters. Data comes to the system from A, and on leaving the system goes to D. A and D are two members of the public, and not under the control of the system. α, β, γ, δ, B and C all do various essential parts of the task in hand, and are under the control of the system manager. A might well give his information in any form—perhaps even not entirely relevant matter communicated in pencilled script on random rough paper. D demands his information in a form he can understand without undue effort.

Although B should not need an interpreter, α is a machine, and will need one. It is evident that, in the case envisaged, and for a very long time to come, the interpreter will have to be human—but it may not be so bad as this. It might be possible to so reorganize the system so that the information from A does not have immediately to go to a machine—so obvious a possibility that it is too often missed. Or maybe 99% of all input is known to be typewritten numerals, typed in standard positions. If so, this can readily be sorted from the odd 1%, which can then be dealt with as an exception. Then maybe a mechanical interpreter, i.e. a character-recognizing machine, would be cheaper and more error free than a human one. Perhaps A is so much under system control that he can be made to use a special typewriter, or even magnetic ink and specially shaped characters—but if he is that much under system control, maybe he could be made to produce information as punched-card, or as punched paper tape. And maybe that would be very much for the good of the system.

Within the system a machine may feed one it matches—or one it does not—man may feed machine, or machine man, or man or machine may feed any combination of man and machine. Where a unit does feed more than one other item it may be that it feeds identical information to each. In a well organized system, however, this is not very likely to be the case. If the system were badly designed, it could well be that it could use more expensive equipment—and take more time—on interpreting than on the real work.

Choice of Interpreter

In considering what kinds of interpreter should be used, several important points should be kept in mind. Firstly, man can accept a wider set of input forms, and produce a wider set of outputs than any machine. Furthermore, he is much more readily taught. Thus, he can learn to read numerical data punched in binary-decimal code as quickly as he would read it written in arabic numerals, or to move his fingers and hands in the right way to operate the input keys of an adding machine quicker than he could write the numerals.

Second, if an interpreter must be used, it is in general very much cheaper to put it at the output of a unit, than at the input. Thus, it is much cheaper to make a card punch, which enables man to produce an output directly in card code, than it is to make a machine which would read script and convert it to card code.

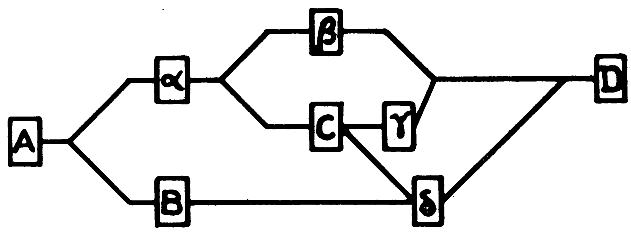

Fig. 1.—Schematic of a system using both man and machine

Third, it is often almost as cheap to produce two outputs from a unit—say, punched paper tape and printed numerals—as to produce one.

Fourth, where information contains errors and is fed to several units, it is obviously best if the error "looks" the same to all fed units. This can only be the case if all the units distinguish the characters of the information by the same features or "qualities." If the units are a man and a machine, and both read binary-coded decimal holes in a punched paper tape, then either will respond in the same way to a mispunched hole. But this is not true in a case like that illustrated in Fig. 2. These are two (very bad) "characters" designed solely to illustrate the point. In each case the blobs or bars are intended to be written in magnetic ink. Man recognizes the characters by noting that they are arabic numerals, whilst the machine counts the number of blobs. Supposing a blob is missing, or is not magnetic. Then, unless the man counts the blobs—in which case why have the rest of the figure?—man and machine will read the character quite differently, and the man will have missed the error. Thus, if a character-recognition device is to be used as an interpreter, then it is preferable that it should recognize the character in the same way as a man would. Furthermore, as will be shown later, this is likely to be the most efficient way of recognizing characters.

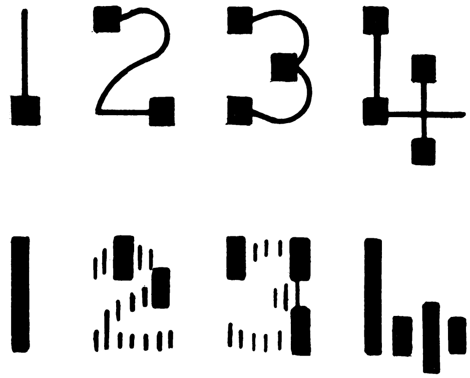

Fig. 2.—Special characters, designed solely for the purpose of the text, but purporting to be recognizable by man or machine

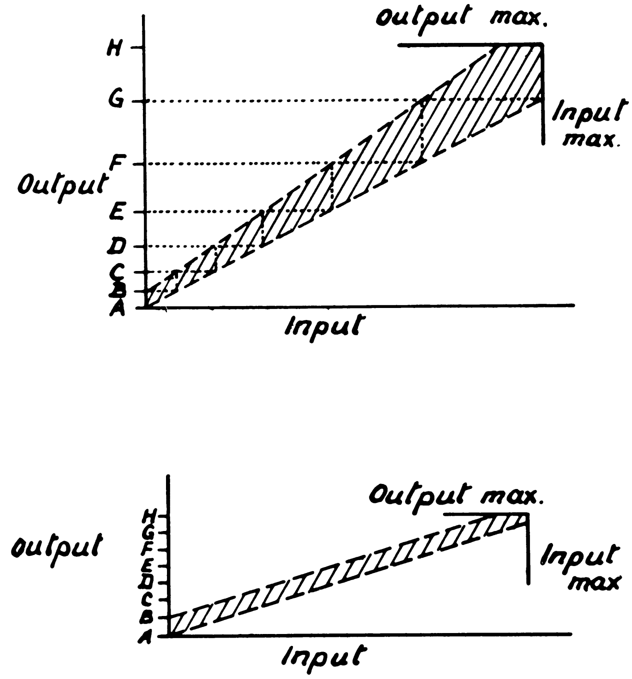

Fig. 3.—Graphs illustrating uncertainty in correspondence between the input and output of a device

Assessment of Character-Recognition Systems

In what follows, interpreters are considered in a very generalized way. From the conclusions of this generalized consideration it is possible to make some assessment about how to judge if a character-recognition system stands a chance of being a good one.

In general, an interpreter has a set of input states, each member of which causes a distinguishable and corresponding output state. Members of a set of states can be distinguished by a combination of "qualities" (one state might be a combination of a green light and a sound) and by the magnitudes of the qualities.

A simple kind of interpreter is what might be called a *magnifier*. The input states are all of the same "quality," but vary from each other in size. To each input state there is a unique output state, and each output state corresponds to a unique input state. Output is of the same quality as input, but differs in size. Examples of magnifiers are amplifiers and microscopes; the one perhaps enables the small signal from a magnetic tape head to drive a loudspeaker hard enough for us to hear it; the other separates the small input signals so that they can be individually recognized.

Looked at from the point of view of its being an interpreter, a *transducer* is very similar to a magnifier. The members of the input set are all of one "quality" and differ only in magnitude, and this is also true of the output set. But the "quality" of input and output is different. Thus, a voltmeter has as input a set of electric potentials, and as output a set of pointer deflections. It enables man to "see" an electric potential. Similarly, a loudspeaker lets us "hear" an electric current; a magnetic tape head allows an amplifier to respond to magnetized regions on a magnetic tape; and a photo-cell enables an amplifier to react to a set of light fluxes.

An input or output state whose members are distinguished by a variation in size of one quality can obviously have its states represented by one numerical parameter, for example by distances in a Y direction on a graph. The distance apart of any two such output states can then be defined as the difference between the two corresponding values of Y.

Hence the behaviour of a magnifier or transducer can be represented on a plane, by a graph as shown in

Fig. 3(*a*). The relationship between input and output is shown as a band and not as a line, since in all practical devices there is uncertainty. A given input might produce any of a range of outputs. There will also be a practical maximum value of input and output. Thus, if Fig. 3(*a*) represents the performance of a device, although this device might naïvely be considered to have an unlimited set of output states, and to respond to an unlimited set of input states, it can be seen that, because of the uncertainty about the precise output corresponding to any given input, the device in practice can only discriminate a limited number of inputs—in the case in the figure, at most seven.

If the Y axis is distorted, so that the uncertainty band is of constant width, as in Fig. 3(*b*), any pair of outputs which are equally liable to confusion are an equal distance apart.

Even the device of Fig. 3 is over-simplified. The relationship between input and output cannot usually be shown as a sharply defined band, but rather one that blurs off at the edges. But the general idea still holds.

Input-Output Considerations

Beauty is said to be in the eye of the beholder. In a similar way it is true that the inputs and outputs of a device must be thought of in the context of the nature of the device that feeds it, and of that it feeds. Thus a tape-deck amplifier is only intended to be sensitive to the wanted outputs of the tape reading head. But it might also be sensitive to other inputs, such as changes of temperature, changes in the light flux around it, or to acoustic inputs. The effect is to increase the uncertainty in the relationship between wanted input and wanted output, and is therefore wholly bad. Hence any amplifier or indeed any interpreter should have its internal state affectable only by those inputs it is meant to have, and should only be capable of giving the output responses it is intended to give.

This conclusion is as much true of a character-recognition device as it is of any less complex interpreter. It might be noted in passing that one of the greatest assets in man is his power of concentration. A man uses prior knowledge so to modify his input mechanism that he is sensitive only to relevant input. This is the reason why a truly bilingual man—who can, shall we say, speak French and English—will often miss the first sentence spoken to him if this happens to be in the other language to the one he expects. The fact that man is so built that he can only absorb information at a maximum rate of, say, 45 bits/sec, when coupled with his ability to switch this 45 bits of attention to any prior-determined kind of input is probably of the greatest importance to him. He is bombarded by an enormous number of bits of information per second—yet avoids becoming overwhelmed with the confusing surfeit. There is a lesson here. In practice no character-recognizing device should be capable of distinguishing too finely between too much.

Character recognition devices have a coded input,

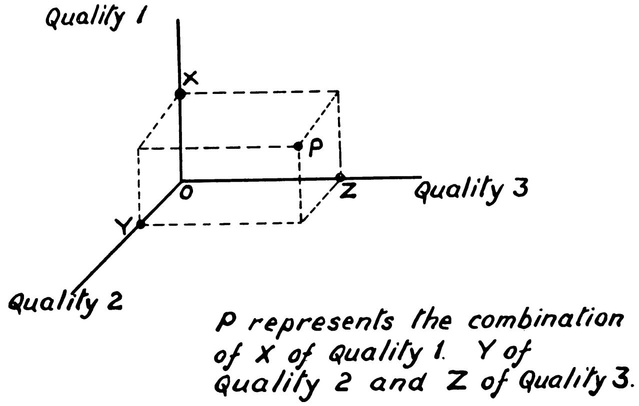

Fig. 4.—Showing the representation of a three-quality state in three-dimensional space

and differ in this way from more simple interpreters such as magnifiers and transducers.

A device has a coded output if the various output states are distinguished by a combination of various quantities of several qualities. These states can be defined by a number of parameters equal to the number of qualities. A state depending on n parameters can obviously be represented by the position of a point in an n-dimensional space. Fig. 4 shows an example of such a representation where three qualities are involved, P representing a state which is a combination of X of quality Q_1, Y of quality Q_2, and Z of quality Q_3. If there is uncertainty in X, Y and Z, there will be uncertainty in the position of P, which will then be represented by a region in the space rather than as a point.

P could be precisely located in the space by an infinite number of other sets of independent parameters. It could, for example, be located by its distance from O, the angle OP makes with the 1, 2 plane, and the angle OP makes with the 1, 3 plane.

Or—a more complicated representation—since there is only one parabola with axis OX and O as vertex through any point P, P could be specified by the length of the latus rectum of the parabola through P, the angle the plane of the parabola makes with OZ, and the distance of P from O along the arc of the parabola. If a new space were now constructed in which the new parameter were the axes, the distribution of points in it would differ greatly from that of those in the old space. But, with either of the new representations, the region of uncertainty about any point would still be a continuous region surrounding it.

In general, if a space has parameters $x_1, x_2, \ldots x_n$ one can construct a new space with parameters $y_1, y_2, \ldots y_n$, where $y_1 = f_1\,(x_1, x_2, \ldots x_n)$, $y_2 = f_2\,(x_1, x_2, \ldots, x_n)$, etc. The new space will represent all the old ones provided f_1, f_2, etc., are such that if the x's were independent the y's are also independent. If $f_1, f_2, \ldots$ and their inverses are continuous and single valued, the uncertainty in P will still be a continuous region around P.

The resulting change of space has altered the code of the representation, and a device that recasts a representation in such a way is called a *recoder*.

It might be that as a result of the recoding all the required points occur in a sub-space of the space, having fewer parameters. Thus, in Fig. 5 all five points in the system are on line *l*. A single parameter system *l* is therefore sufficient to represent the points, since the other possible dimensions are redundant. Where a reduction in dimension is produced in this kind of way, any uncertainty about the point is still represented by a continuous region surrounding it.

This reduction of discrimination parameters is nearly always very valuable. It is equivalent to defining new qualities out of combinations of the old ones. If a set of ten concentric green circles are examined through a 100×100 matrix, it is possible to recognize which circle is present by looking for green in each of the 10,000 matrix elements. This gives a 10,000 quality—10,000 parameter—representation. Evidently, however, the system is better looked at as a one quality-one parameter representation, as circles of given centre varying from each other in size.

It might seem at first that to have fewer defining qualities in this way must increase complexity of the quality involved, and so achieves little. This is not true. What, in fact, it does is to make the quality more specific. From man's point of view, as a "universal recognizer," it increases the complexity of the quality. From the point of view of a device whose nature is such that it responds only to the quality, the quality is the only one that exists and thus could not be more simple. Thus a sharply tuned Helmholtz resonator will respond only to an acoustical wave of very definite frequency. Yet it is a very simple device.

Likelihood of Confusion

In general, in a space representing a set of inputs or outputs, the size of a region of uncertainty will vary from place to place. It is always possible, however, to so distort the axes that the size is constant throughout the space. If this is done the distance between any two points in the space is a measure of the likelihood of confusion between them.

It is evident that there is an advantage if the various states between which one has to discriminate are as far away in the space as possible from their nearest neighbours. This means that they should be uniformly spaced. Written characters possibly started as pictures representing the ideas they were meant to represent. Thus, it is quite possible that the arabic 1, 2, 3, etc., started as the drawing of 1, 2, 3 sticks. The next stage would be to lay the sticks out so that the pattern they make is recognizable in itself, without counting. It is reasonable to make the hypothesis that, as many years went by, the actual shapes used would evolve, until they made a set in which each is most readily distinguished for the other (provided suitable recognition parameters

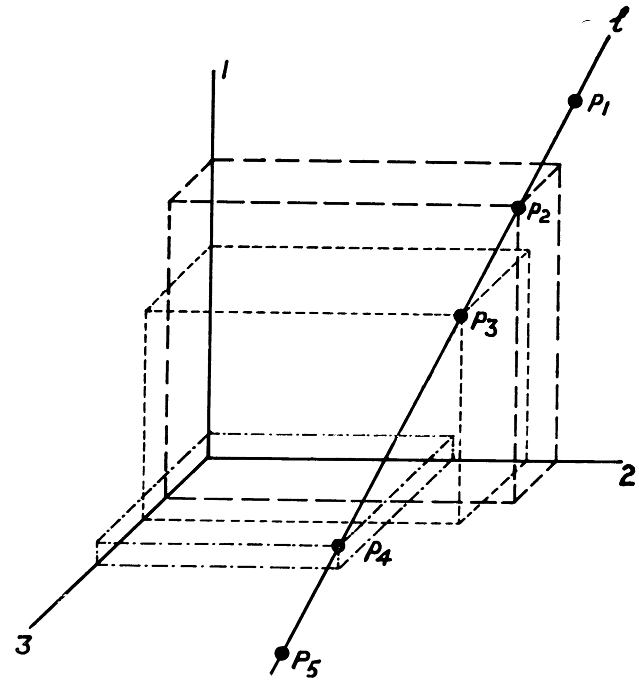

Fig. 5.—Points P_1, P_2, P_3, P_4, P_5 lying on a line represent five states unnecessarily being represented in a three-dimensional space

are chosen). There is no such unique set, of course; in general, a set could be made of any four two-state parameters in order to represent all numerals, and five parameters to separate all alpha characters, and it is reasonable to suppose that the shapes have evolved so that this is all that is needed.

In an *n*-parameter space of this sort, in the special case where each quality has only two values, there or not, there are 2 points.

The choice of such a set is equivalent to fitting a set of points in a parameter space, and so the inevitable geometrical relationship between neighbouring points must be of interest. In a space of n two-valued parameters each point has n nearest neighbours, $\frac{n!}{(n-2)!\,2!}$, next nearest, $\frac{n!}{(n-3)!\,3!}$ next nearest, and so on, the spacings being in the ratio 1, $\sqrt{2}$, $\sqrt{3}$, and so on. Using these formulae, we can deduce the relative spacings of numerals, or of alpha-characters, from their various neighbours, i.e. the different amounts of confusion which we might expect between the various characters of a set. The amounts of confusion which occur in practice can be measured by suitable experiments, the results of which seem to justify the predictions, and thus the general way of looking at the problem.

From this it would seem that the ideal character-recognition machine would look for the presence or absence of a limited number of suitable qualities, and by its nature should be able to react only to the desired qualities.

Such a device would be inherently error-free, insensitive to character location or aspect, or to meaningless variations between examples of the same character, and it would be basically simple and cheap. If the qualities used by the character-recognizing machine were the same as those used by man to distinguish between the characters, then man and machine would respond to errors in the characters in the same sort of way. This feature in a character-recognition machine would give it a very important advantage over any machine without it.

The task of discovering what are the basic qualities a man uses in distinguishing between patterns is very difficult. We adjust our attention—and so our input templates—to meet the task in hand, but we do this quite unconsciously, and rarely know how we do it. We can only discover what features we use by much introspection, insight, and experiment. Hence, the basic research, necessary in order to make the ideal character-reading machine, is of necessity long and arduous. In the meantime there is a real place for less ambitious projects.

Conclusions

First, one should not resort to character recognition until one is very sure that one cannot reorganize one's system more efficiently without it.

Second, research should aim at finding the minimal number of features which need be used to recognize characters. There is evidence that man uses such a minimal set, and apart from the obvious advantages in making a machine use the same criteria as man, there is much to be said for trying to get insight to these criteria rather than to attempt to devise new ones.

Third, in order to minimize error and promote simplicity the actual detection apparatus should, by its inherent nature, be able to detect only the relevant features.

I have long thought that the relevant criteria might be circular and straight-line elements in a few standard relative positions. A circular element, in this context, is evidently an arc whose length is of the overall size of the figure, and whose radius of curvature is of like magnitude, whilst a straight-line element is of similar length but of very large radius of curvature.

A circle can be detected in a figure by correlating the figure with itself rotated about the right centre, i.e. by finding the extent to which the rotated figure overlaps the original; similarly, a straight line in a given direction can be detected by correlating it with itself shifted in the required direction.

However, such a simple scheme will not quite do, for one wishes to know the direction of any straight lines, and to be able to detect arcs without knowing their centres.

In another paper* Dr. Clowes describes the ingenious way in which he has solved some of the problems.

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* See p. 121.

Summary of Discussion

The Chairman, Mr. R. H. Tizard (*Fellow of Churchill College, Cambridge*) said character recognition was a subject on which much had been written and said, but little had yet been achieved in practice. It was an extremely difficult subject but one of great interest to all kinds of people, from bank managers to specialists in research on the human brain. In Britain applications on a commercial scale were just beginning and it was certain that there would be great developments within the next ten years.

It was very appropriate that the subject should be discussed at the Conference, and they were fortunate in having two speakers from the National Physical Laboratory to discuss it. Mr. Newman, the first speaker, had been with the N.P.L. since about 1947, joining there from E.M.I., and had been largely responsible for the development of the pilot model ACE, one of the first digital computers produced in Britain.

After the paper had been given, **The Chairman** asked Mr. Newman to elucidate his apparent "hunch" about the way in which human beings recognized patterns. He had apparently rejected any method of recognition by which non-essential information was discarded to leave only the small amount needed to specify a particular character. Yet it would seem that that was just the way in which human brains might work.

Mr. E. Newman said that a multi-dimensional information space, representing the information in, say, a character, could obviously be so arranged that all the points representing different characters would be crowded together, and therefore easily confused; with a vast array of possibilities, even a trivial error could lead one to a completely wrong character. Even spacing of the character-points was necessary, to ensure that trivial errors led to deviations from the true point which were small compared with the spacing between the points.

With sufficient ingenuity, it is usually possible to transform a space, in which the points are too crowded, into a better one, by defining new dimensions as functions of the original one. Human beings were very skilful when looking at shapes and finding ways of recognizing them and transforming the information until the spacing was uniform. Obviously, though, it was difficult to do this in a machine.

This general idea was illustrated if one compared a correctly-designed error-correcting redundant code with a bad code having useless redundancy, which would merely confuse.

Mr. I. V. Idelson (*Mullard Equipment Ltd.*) said everyone felt he was an expert on human beings. On the general n-dimensional picture drawn by Mr. Newman, there was the very real difficulty that if one tried to visualize the higher stages one tended to think in terms of linearity. There might be one characteristic in the whole range at which one might look. One might, for example, look at all the characters from "0" to "9" to see if there was a straight line. That might give a great deal of information about the difference between "0" and "1" but less information on the difference between, say, "4" and "6".

It seemed to him, therefore, that there might be a fundamental difficulty in looking for a number of characteristics which could be applied to the whole set of numbers. He considered it was basic that the characteristics chosen should be a function of the set. While it was possible to distinguish, in one way, between two different numbers, there was a different problem in distinguishing between, say, the figure "6" and the letter "b". In his view the three-dimensional cube approach was the right one.

On the figures mentioned by Mr. Newman, it might be possible to sort them into sets and then try to distinguish between those which had relevance to other characters. His method was really the same as that mentioned in the United States. There they spoke of pre-press setting. Given a character, one did not take it on to a recapitulating grid but introduced a translation process. The auto-correlation method was pure translation. From 9 characters one got 9 different kinds of signals and studied the difference between them. He believed there was powerful evidence that that played at any rate some part in mental processes in animals. In this connection there had quite recently been an interesting article on how the frog saw, published in the transactions of the Institute of Radio Engineers. There was there strong evidence of some pre-processing. Did Mr. Newman believe that one needed, first, to find a translation and then, after the translation, to look at the characteristics?

Mr. Newman said he agreed with many of Mr. Idelson's comments. He was sure people recognized every set of things in a different way. He suggested that in the recognition of written numerals one looked not for the amount of straight line but for a combination of curve or circle and straight line. He thought that one adjusted one's information to fit the kind of discrimination one expected to have to make. Thus, one would look for something different if one expected a combination of both letters and figures, compared with when one did not. Experiments showed that to be so.

If people were given figures to designate they took less than 0·3 seconds to distinguish between one and another; but if they were given a set of alpha characters to discriminate, they took longer. With a combination of the two, they took longer still. If, however, one completely misled a subject, telling him he was to see the combined set, but giving him only the numerals, he showed the long discrimination time until he realized what had happened, and that he had been cheated.

This switch-over from one frame of reference to another was interesting. If a man who spoke both English and French had been speaking and being spoken to in French and was suddenly spoken to in English, there would be a break in his understanding until he realized what had happened: the same thing would happen again when he was switched back to the original language.

On the question of whether there should be pre-processing, his answer was both yes and no. If that meant having two translators instead of one, then he personally would prefer not to have it. But if it was suggested that the translation process should be very simple, recognizing the features of the character which it was desired to discriminate, then he felt this was right. If one wanted to recognize a sound wave of 1,000 c/s one did it with an acoustical resonator tuned to 1,000 c/s, and did not complicate matters by "looking" at it with an oscilloscope, plotting the waveform and then seeking to deduce the 1,000 c/s by means of calculations.

It was necessary to find something which, by its very nature, recognized such an acoustical wave and, similarly, it was necessary to devise something which recognized relevant features of characters by its very nature, not by means of anything comparable to an oscilloscope and complicated calculations.

Mr. M. Nadler (*Compagnie des Machines Bull*) said that in considering the mental processes involved in character recognition they were really entering the field of the psychologist; psychological research in the field of pattern recognition, for instance by the Gestalt school, had produced some extremely interesting results, in depth and complexity exceeding what had been mentioned here.

Considering the question of the mental processes of language translators, which had been touched on here, human translators are not the simple four-terminal devices in question. If a bilingual interpreter was interpreting between a Russian and an Englishman, for example, and the Englishman suddenly started speaking Russian, the result would be that the translator would begin to translate his words into English for the benefit of the Russian until he realized what was happening.

One might ask 200 visitors to complete a particular form by hand and thus secure quite a large sample of characters, as has actually been done at M.I.T., but that would still not be representative of what the human brain could distinguish. French advertising posters illustrate what transformations or, rather, distortions of characters will still permit the message of the advertisement to be read. Psychological experiments show that letters and numerals can be enormously "de-redundancized" and yet still remain recognizable. An imaginative poster designer, on the contrary, can introduce a large number of contrast reversals within a single character, for example composing it of bars of alternating contrast (black on white, white on black) in a way which would render even a sophisticated scanner of little use. He mentioned those points only to show that the process of character recognition by human brains were far more complicated than had been realized by some working in the field of character recognition by machines.

Fortunately, though, a machine did not need to use the same techniques as human beings and therefore quite different criteria could be used. In any survey of character recognition it would be in order to mention the work of Karl Steinbuch of Germany, one of whose methods, involving use of a potential analogue, was reported at a Conference of the Institution of Electrical Engineers in 1959 and also at the UNESCO Conference in Paris the same year. Another of his systems used a scanner which completely ignored the contrast sign and was affected only by transitions from one contrast region to another.

Mr. Newman said he felt Mr. Nadler had really missed the point. Clearly, if one wrote a figure "2" on paper, the characteristics of the figure had something to do with space and nothing to do with colour or smell; and therefore whatever might be the right ones to recognize them by, they had to be deducible from the spots on the paper. Therefore, the characteristics whatever they were could be obtained by transforming the "dot" representation.

To recognize that a set of dots contained some that were in the shape of a "2", it was necessary to know the character as a curve, rather than as a number of dots. Character recognition would lose many of its advantages if the machine were to read differently from man, and therefore make different kinds of mistake. Why try to combine two really quite different representations in one shape?

Dr. A. J. Mayne (*University of Leeds*) said Mr. Newman had not mentioned the possibility of character-recognition being achieved by the aid of learning-machines, using general circuits not specifically related to the types of character which had to be recognized, adapting itself to the recognition of any group of characters with which it was presented in its experience, intended to be able to recognize any type of character so presented to it. How far had that type of device been useful in the recognition of numerals and letters?

Mr. Newman said if one could devise the perfect learning machine, learning in the same way as human beings learned how to recognize characters, that would be good; but it had to be accepted that all devices were far from being able to do that. It was necessary to work one stage removed and find—not how much one could gain by using very complicated learning techniques in machines, but whether there was any advantage in using smaller-scale learning techniques. There was much to be said for human beings using their own learning facilities, to pre-judge and determine, from what they had learned, how best to recognize characters.

If it were suggested that on a limited scale a machine might modify its criteria according to its results, he believed much could be done to produce gradual adaptation in a system. While in principle this was difficult, the fact that it could be done had been shown at a National Physical Laboratory Symposium at which Mr. Chairman had devised a program which improved its ability to recognize characters by such a means.

The Chairman said he regretted having to cut short a discussion when it was just beginning to warm up, but time limitations made it necessary to do so.

Everyone present would wish to show their appreciation of Mr. Newman's interesting comments by his applause.

Mr. H. McG. Ross (*Ferranti Ltd.*) (*in a subsequent written contribution*): Mr. Newman has stressed the need that any automatic character-recognition system should be based on a process similar to that of human character-recognition. An example of the application of this principle (which, in fact, violates the principle), is that the response of the human eye to light and shade is essentially of a logarithmic nature, whereas most electro-optical processes, and almost all electronic processes, are essentially of a linear nature; it is quite difficult to make electronic circuits to give a logarithmic response. In another field, all the essential stages in the photographic process are basically logarithmic, and this is a prime reason for its success.

Mr. Merry showed a most impressive lantern slide (Fig. 9, p. 142) giving a 3-dimensional representation of the electrical signals obtained with an electro-optical system when reading a poorly-printed letter H. This emphasized the major achievement which has been attained in developing an automatic system which is capable of interpreting such a record. However, if this representation had been made on the appropriate logarithmic basis, it would have displayed in an even more startling manner the problems which have to be faced in such a system.

Correspondence

To the Editor,
The Computer Journal.

Dear Sir,

"Prime Number Coding for Information Retrieval"

Having much enjoyed reading Cockayne and Hyde's article in your JOURNAL (Vol. 3, p. 21), I was surprised to read Mr. Fairthorne's criticism of it in Vol. 4, p. 85, as also his even more severe review in *Computing Reviews*, No. 341, December 1960.

Mr. Fairthorne attacks the article on three main counts.

(1) That this is not "Information Retrieval," as understood by Mr. Fairthorne. But, I submit, in the absence of an Académie Anglaise the majority of the informed users of a phrase is always right, so that the meanings of phrases evolve and the limits imposed by the original definition are not always relevant. Perhaps the article is concerned with a simple case of Information Retrieval as understood by most workers in data processing today, even if the problem described lacks some of the features which Mr. Fairthorne has to worry about.

(2) That the authors provide no bibliography and have probably not read up their subject adequately. I am particularly shocked by this criticism, for it implies that Mr. Fairthorne believes that duplication of work is a prime evil and that the first thing to do if one has an idea is to make absolutely certain that no one else has thought of it already. Obviously skill in finding one's way through the jungle of technical literature is a most valuable asset, but is it essential? I suggest that often the right thing to do to a good idea is to try it, and if it works, pass it on. If one has a problem of this sort and is considering spending thousands of pounds in setting up a system to deal with it, of course one would be wise to consult the literature first, but that is not the point.

(3) That the method described is uneconomic and technically incompetent. I believe that Cockayne and Hyde, like many others, use a computer which was acquired to do certain routine work which does not take up all of its time. If this is so, the additional cost incurred by leaving it switched on for a few more minutes each day is trivial. If one has a computer one may as well use it; Mr. Fairthorne may call this sentiment "a determination to use automatic machinery at all cost," but most people would regard it as good sense. We do not know the full technical and administrative background; but neither Mr. Fairthorne's own valuable article in your JOURNAL (Vol. 1, p. 36), which also I re-read with much enjoyment, nor his present contributions suggest any method which is obviously more economical and would not require substantial additional equipment, labour or organization.

It is the referee's job to decide whether an article is sufficiently interesting, useful, original or important to be worth publishing. I do not think he has failed us here. It is unfortunately somewhat unusual that interesting points of detailed practical experience in the field of commercial data processing are written up in a manner understood by the non-specialist, as Cockayne and Hyde have done. If they are mad, one wishes they would bite some other potential contributors!

Yours sincerely,
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