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Abstract
From a dissertation read before the Society on Friday, 4th November, 1966

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COMPUTERS IN MEDICINE

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The subject of this dissertation is Computers in Medicine and even those who have had nothing to do with these machines will be unable to ignore them in the very near future. A brief account of how they work is given here, followed by the description of a few of their applications in Medicine. In fact, learning to programme the machine is very simple, and the University Computer unit runs a special course three times a year for this purpose. Many people think of the computer as something between a glorified adding machine and a sort of god that can do anything, whereas in fact the truth lies somewhere in between.

PROGRAMMING

It should be emphasised that usually the programmer need know very little mathematics. The programming language is a standard one, and the person who has a particular skill, say in mathematics, can write out a programme for carrying out any particular procedure. He might, for instance, devise an ingenious programme for evaluating the square roots of complex numbers. He could publish this programme in a magazine, and then anyone else wishing to do the same thing as part of another programme could copy this out word for word without having any understanding of the method involved. These "little programmes" are termed Algorithims, and the index of these is by now very extensive.

There are several features of any computer which make it an extremely versatile machine, but three should be stressed in particular —

(1) it can carry out simple operations exceedingly fast; for instance, the machine can add two digits together in about a millionth of a second, and all multiplication is done by repeated addition.

(2) it can follow a chain of instructions. Thus to work out the equation:

$$x = (a \times b) + (c - d)$$

it is necessary to do the following:

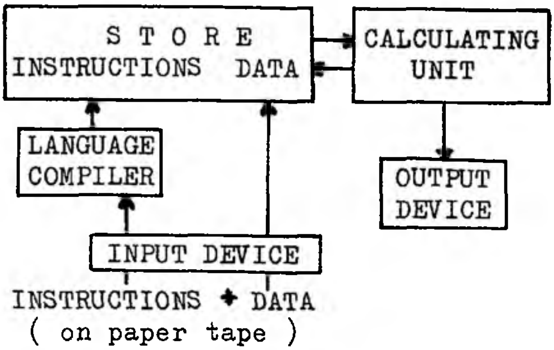
multiply a by b
subtract d from c
add the first result to the second
print the result and call this x

and the computer can follow these instructions in that order.

(3) it can "choose" between following one set of instructions or another according to the result of some intermediate calculation. Thus if one were trying to find whether a number were divisible by 3, 5, or 9 one could tell the computer:— if the result = a whole number then print the result, otherwise try the next one. If there is no "next one" then print 0.

These properties look simple, but enable a very wide range of problems to be tackled. The programme often looks long winded on paper, but the machine is extremely fast.

The following diagram shows the essential features of any digital computer.



The instructions and data are usually coded in the form of punched paper tape. Each key depressed on a special typewriter produces a different combination of holes across the tape, and in the machine these holes can be "read" by means of a light shining through them onto a row of photo-electric cells (the input device). Most machines will accept magnetic tape and punched cards as well.

All instructions for the machine are written in a special programming language (usually Atlas Autocode in Edinburgh) and this is very like English; but when the language compiler receives a word such as "add" a + b it will in turn switch on the various devices inside the computer required to add these two digits together.

The store is the memory of the machine, performing a function similar to that of a tape-recorder, and can be considered as a large number of boxes holding numbers, which can be transferred to and from the calculating unit or printed out as directed by the instructions. The output device is usually a "Line Printer" although paper tape is sometimes used and this can be fed back through the special typewriter to produce a printed result.

USE OF THE COMPUTER

To illustrate the use of the machine a programme can be considered. For instance, it might be required to find the number of times a letter occurs in a sentence. Regarding the store as a series of boxes, a Flow Diagram for this programme would appear as follows:—

(1) Begin
(2) put the letter to be counted into box 1
(3) start reading the letters of the sentence, one at a time, into box 2
(4) if the contents of box 1 = box 2 then add 1 to box 3, otherwise go on to the next letter
(5) if the last letter of the sentence has been reached print out the total in box 3
(6) stop.

These instructions can easily be written out in Atlas Autocode, followed by the data which in this case would be the letter to be counted, and the letters in the sentence.

Now this programme needs very little alteration to count the number of times a particular word, or particular phrase, occurs in an entire book, and it was this method which was used to determine whether in fact Paul wrote all the chapters attributed to him in the Bible since any writer characteristically uses particular phrases with a particular frequency. Another possible use of this programme might be to search through vast amounts of literature for a particular reference such as, say, "Acute Tubular Necrosis". This idea could be extended to make the machine print out a list of references of articles which contained both the phrase "Acute Tubular Necrosis" and the phrase "Hypertension" thus providing an interesting method for extracting any desired information from any amount of literature Others have tried to apply similar programmes to the automatic translation of language, but so far without very much success.

Another idea which has been put forward is the Automatic Library Facility (ALF). Suppose Dr. A. has certain items of information I_1, I_2, I_3 and I_4 (which may be symptoms, signs, or results of tests, etc.) concerning a patient, but that he requires more information on the differential diagnosis than his own knowledge or experience affords. Normally he would consult his own colleagues and the available literature but it is now proposed that in addition he consult ALF. Asked for the very first time by Dr. A. what diseases are associated with I_1, I_2, I_3, and I_4, ALF will answer none, which of course is no great help to Dr. A. who can himself think of two such diseases D_1 and D_2. ALF stores these two. When next asked a similar question by Dr. B., ALF obviously produces D_1 and D_2, one of which is news to Dr. B., but who notes that ALF has omitted a third possibility, D_3. In effect, ALF now "knows" the associations of Drs. A. and B. and clearly after 100 doctors have made their enquiries, ALF's suggestions will be of use to any doctor who does not know as much as all the previous enquiries put together.

Furthermore, as knowledge about individual diseases accumulates, ALF could also indicate an exhaustive set of other differentiating signs, tests, etc., and if told of the methods of treatment used together with the results obtained, the computer will be able to compare these and offer advice to others on the best treatment available to date.

Yet another important use of the computer organisation described is in drug testing. If it was mandatory to report the prescription of any new drug, together with any symptoms appearing which were not present before the drug was prescribed, then it would be surprising if side-effects were not recognised very soon. In this context it is worth remembering that even after thalidomide, the problem of congenital abnormality remains, and a systematic, statistical analysis of all relevant data could be a powerful research tool.

There is a continual search for tests which are absolutely diagnostic of specific diseases, and the computer can be of value in this field also. For instance, although there may be no single test available, it is often the case that a certain set of symptoms, signs, etc., may be absolutely diagnostic, and statistical analysis of all the factors relevant to each disease may indicate cases where this is so. The principle can be extended to include assessment of the significance of the various waves produced by ECG or EEG machines. Then in certain acute disease, such as myocardial infarction, meaurements of B.P., pulse rate, or blood chemistry may be carried out by automatic equipment already available, and the resultant data analysed by the machine which would indicate the treatment required, or might even initiate such treatment in some cases. The advantage of the machine when prescribing a routine of treatment is that the needs of the individual patient are catered for, which should be better than using a standard routine.

There are many other uses for the computer within the hospital and an example is as an aid to the bacteriologist.

Bacteriological identification proceeds by submitting a specimen to a number of tests, deciding on the basis of the results which are the most likely possibilities, then carrying out further tests to differentiate between these, and so on until identification is established to the bacteriologist's satisfaction. A computer procedure has been developed to assist the process as follows: the results 'phoned in to the computer centre may be as in Fig. 1.

Fig. 1

Computer Input	lactose = acid
	sucrose = acid
	indole = negative
	motility = negative
	H_2S = negative
	Urea = negative

At the centre these are typed out, and the resulting piece of punched tape entered into the computer. Within a few minutes it will print out the most likely bacteria in order of preference, and also the next set of tests which will most efficiently discriminate between these. (See Fig 2).

Fig. 2.

Sh. Sonnei	100	relative likelihood
Klebs. Rhino scleroma	50	
Sh. Dysenteriae type 1	1.32	
Alk./Dispar group	1.32	
Sh. Flexneri	.69	
further tests:—		
Xylose	1.00	relative discriminating power
Sorbitol	.90	
K.C.N.	.86	
Dulcitol	.79	

In actual cases it has been found that the computer has agreed with the bacteriologist in all important respects, and has generally established the diagnosis using fewer tests. Of even greater benefit to the patient, however, is the fact that the computer keeps up to date with all the latest developments in the field.

COMPUTER CENTRES

It should be noted that in most cases, the machine spends far less time calculating than the operator takes in deciding what to do with the results. A Time Sharing technique is usually used so that data is fed in to small machines, perhaps one in each hospital eventually one day, and a large central computer turns its attention to these to suit itself, thus saving time and money. The central machines are being set up at various places in the country for general University use, by the government, and methods are being developed by which these machines can communicate with one another also, which will have vast potential one day. As far as Medicine is concerned the same device which can communicate with world diagnostic or information networks could be used to calculate nursing schedules or teaching timetable, or may compare the vital statistics of one hospital with another to indicate how an epidemic is spreading.

The next difficulty is that as the requirements get more complicated, so programming the machine takes longer, and several centres are trying to devise systems in which the machine programmes itself. As an example, various attempts have been made to write a programme for the computer to play chess. For a man to tell the machine what to do in every possible situation in advance would take a very long time. However the machine can survey the positions of all the men on the board and then try a move at random. If this results in immediate gain, or if it eventually wins the game, it will try the same moves for each time the particular combination of men recurs in future games. If it loses, it will remember what its opponent did, and will use his moves in future instead. Analysis of game theory in this way has led to important advances in other sciences, and may well be of use in the medical field in the future.

Altogether the computer may well provide the spectacular changes in Medicine in our generation that antibiotics and bacteriology provided for our forefathers, and time spent acquiring some knowledge of how it works while at University is most unlikely to be time wasted.

DIAGNOSTIC PROBLEM

Set by Robin B. L. Ewart, M.B., Ch.B., B.Sc.

(answer on page 44)

Subject:

C.S., married, female, aged 33. Housewife.

Past History:

1. Usual childhood illnesses.
2. Pneumonia on three occasions between the ages of 3 and 5 years.
3. Rheumatic fever, aged 9 years.
4. Tonsillectomy, aged 10 years.
5. Appendicectomy, aged 16 years.
6. The patient had two normal pregnancies, aged 23 and 24 years.
7. Perforation of duodenal ulcer, aged 25 years. — Gastroenterostomy.
8. Gradually progressive exertional dyspnoea began, aged 27.
9. Two miscarriages, aged 28, followed by tubal ligation on the grounds of rheumatic heart disease.
10. Mitral valvulotomy successfully carried out, aged 29, with relief of symptoms.
11. Recurrence of classical acute rheumatism, aged 30.

Following discharge from hospital, the patient seemed initially to be well but 2½ years later was readmitted with the following complaints —

1. Tendency to bruise on minor trauma, — 1 year.
2. Marked emotional lability — 1 year.
3. Progressive increase in weight amounting to 9 lbs. in the previous six months.
4. Increasing lethargy — 3 months.

Social and Family History:

Not relevant.

Examination:

Plump, plethoric women, looking older than her 33 years.

Marked bruising of all four limbs was evident.

C.V.S. Pulse 102. Regular in time and force. B.P. 180/110. Auscultation of the heart revealed the classical signs of mitral stenosis and incompetence. There was no sign of cardiac failure.

All other systems essentially negative to full examination.

Findings:

1. History of bruising, emotional lability, increasing weight and lethargy.
2. Plethora.
3. Diastolic hypertension.

What is the diagnosis? How would you confirm it?