'awful dark and the blinding bright which lay below and above the tiny, pastoral world of man considered solely as man'.[23] The professor would, of course, insist that this is the authentic Newman. He would be right in implying that this Newman was conscious of an unredeemed part of his nature that could easily be tempted into pride and self-sufficiency. But I do not think he would be right in saying that Newman ever saw in humanism as such the unredeemed or unredeemable pride of the human intellect.

It will be seen from the discussion that both these books will have immense importance for Newmanists. Professor Culler's views certainly deserve serious consideration, and all Newmanists will be grateful for his scholarly and fascinating biography. As for the French edition of the memoirs, it will have value for English Newmanists even after the publication of the English edition of the same. For no one in this country needs to be persuaded of the importance of Fr Bouyer's notes.

23 A. D. Culler, *op. cit.*, p. 230.

SIDELIGHTS ON ELECTRONIC COMPUTERS

Michael Hoskin

Electronic digital computers or 'brains' were originally designed, as we saw previously,[1] for use in the computations which occur in business and in scientific research; they carry out at great speed 'programmes' of elementary arithmetical and logical instructions which have been precisely formulated in advance. But there are many scientists, from linguists on the one hand to neurologists on the other, who are not confronted with heavy computation but who are keenly interested in other applications of electronic computers. In this article I shall discuss briefly a few of these applications, because although they are of less immediate practical importance they are fascinating in themselves, and in one case at least they have helped in the formation of a new discipline, that of cybernetics, which is helping to break down a little of the excessive specialization which is the curse of modern science.

1 'Automation', in Blackfriars, October 1956, pp. 423-30.

Machines which play games. The mathematical theory of games which has been developed in recent years can be applied to much more serious matters such as economics and even military strategy. The possibility of similar applications of game-playing machines may help to justify the time and money which have been spent on programming a computer to play such games as noughts-and-crosses, draughts, chess and two-handed whist.[2]

As computers are built to handle numbers rather than chessmen or playing-cards the game has to be coded in the form of numbers, though of course this makes no essential difference. In fact some games are really played with numbers in disguise. The game of Nim, for example, is played with piles of matchsticks, but each pile simply represents a number. However, the main interest lies not so much in the coding as in the methods which the machine is told to use in deciding its next move. These depend partly on the success which mathematicians have had in studying the game in question. Noughts-and-crosses and Nim are among the games which have been completely analysed, and the machine can be programmed to play them impeccably. Noughts-and-crosses is particularly simple because the number of possible situations is quite small, and the machine can be provided with a catalogue of these situations and a suitable move for each. But for more complicated games such as draughts and chess, of which no complete mathematical theory exists, the programmer has to choose a strategy for the machine which will enable it in the time available to make a move that is at any rate not completely futile. According to one method, the machine looks ahead as many moves as possible (time seldom allows it to do this for more than two of its own moves and one move by its opponent), attaches some value to each resulting situation, and selects as its next move the one which appears to offer the best possibilities. (This illustrates how the machine is handicapped by its inability to see the game as a whole.) Just how well the machine plays depends in part upon how skilfully the strategy has been chosen. In the first game of draughts ever played with a computer, the machine was instructed to prefer the loss of one of its own men to the making of a king by its opponent. When the opponent was about to make a king, first one and then another of the machine's men sacrificed themselves in a vain effort to prevent this disaster.

2 B. V. Bowden (ed.), *Faster Than Thought* (Pitman 1953), chapter 25.

Among the machines which have been specially made to play games are the Ferranti Nimrod, which played Nim with visitors to the Festival of Britain, and two machines which were built in America for the game of matching pennies. In matching pennies, the opponents simultaneously choose either 'heads' or 'tails'; if the choices are the same one side wins, and if they are different, the other. Each of the two machines was programmed to search for patterns in the succession of choices already made by its opponent and to make its own choice in the expectation that these patterns would continue. The programmers hoped that in this way the machines would improve on the equal number of successes and failures to be expected from choices made at random. Now the two programmes given to the machines were different, and it was difficult to decide theoretically which was the better. To settle the matter once and for all the machines were linked by a third and set to play each other, which they did, to the accompaniment of side bets and cheers from their supporters.

Machines which learn. No one has yet designed a game-playing programme which, by selecting more often those moves which past experience has shown to be successful, will enable a computer to learn its own strategies for play. However, machines have been built or programmed to exhibit other forms of learning, and one of the most interesting examples of is this due to A. G. Oettinger,[3] who programmed the Cambridge University computer to behave in a way usually associated with conditional reflexes. A programme such as this must be seen first of all from the point of view of the experimenter, to whom the machine is a closed box, and then from the privileged position of the programmer, who knows how the illusions are created.

As of course there is nothing to be gained by prodding or cuffing a digital computer, the stimuli and expressions of approval or disapproval must take the form of numbers fed into the machine. What is required of the machine must also be numerical in form. With Oettinger's programme, a stimulus is given to the machine in the form of a small positive integer. The machine, if it responds at all, prints out one of five symbols. If the experimenter approves, he encourages the machine with a positive

3 A. G. Oettinger, 'Programming a digital computer to learn', *Philosophical Magazine*, 43 (1952), pp. 1243-63.

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integer; if he disapproves, he feeds in a negative integer; and if he is indifferent, he shows this with a zero. The intensities of the stimulus and of the experimenter's approval or disapproval are indicated to the machine by the sizes of the integers supplied to it. Owing to the ingenuity of the programme, the larger the stimulus number, the more likely is it to produce a reaction from the machine; and the larger the integer showing the experimenter's approval or disapproval, the more readily will the machine act accordingly. If on the other hand the experimenter repeatedly shows unconcern at the result, the machine may lapse into lethargy and produce no responses, or it may form a habit and always produce the same response. Accordingly, the machine can be trained into making certain responses and discouraged from others. Habits can be formed and broken again, and if one particular response is consistently encouraged, the machine will end by repeating it on the slightest pretext.

The programme by which all this is achieved works essentially as follows. Each of the five possible responses has a varying number R attached to it. On receiving a stimulus, the machine does not print anything unless it can find an R-number which, when added to the stimulus-number, is at least seven: which explains why a large stimulus-number is more likely to be successful than a small one. When this condition is satisfied, the machine prints the response with the largest R-number. For the next round this R-number is altered in a way which depends partly on the approval or disapproval shown by the experimenter. Approval usually increases the R-number, and so despite changes which may occur in other R-numbers the same response is likely again; disapproval tends to reduce the R-number, although several expressions of disapproval may be necessary before it ceases to be the largest R-number and the response changes. It is interesting to see how other features of the behaviour of the machine now follow. To give only a single example: once one R-number is large and the others small, the same response will occur regularly unless the experimenter disapproves sufficiently to reduce the particular R-number until it is no longer the largest.

Cybernetics. The previous example is an illustration of the way in which machines sometimes mimic animals in their functioning or structure. As an example from the field of communication we

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have the striking similarity between the working of the neurons or nerve-cells, which are subject to the all-or-nothing principle of neurophysiology, and the functioning of the relays or thermionic valves which represent the 0's and 1's within a computer. In the field of automatic control we find, for instance, the regulation of the heat of the bathwater by a thermostat and the maintenance of constant body temperature by the nervous system both being achieved through the application of negative feedback: any departure from the required state causes correcting action to be taken. 'Control and communication in the animal and the machine' is in fact the subtitle of Wiener's important book[4] introducing cybernetics. Cybernetics is now too vast a subject to be more than mentioned here, but it is perhaps most remarkable in the varied fields of study which it draws together. It is not often that one comes across a scientific meeting discussing so sweeping a title as 'Les grosses machines, la logique, et la physiologie du système nerveux'!

The solution of logical problems. Logical problems are often best solved by small, special-purpose machines which depend upon the correspondence between alternatives in logic, such as true and false, and alternatives in electrical circuits, such as on and off. The simplest example of a logical machine is perhaps the domestic double-switched electric light, which has two switches A and B and which lights when 'A or else B' is depressed. When a digital computer is to be used, the logical alternatives must be represented in numerical form, and here it is fortunate that pairs of alternatives such as on/off are so common in electronics that they are reflected in the arithmetic used in most machines, which is that of numbers in the binary rather than in the more common decimal form. Each digit of a number in binary form is either 0 or 1, and so it is natural to use 0 and 1 to represent pairs of logical alternatives within the machine. Logical operations then correspond to elementary operations on binary numbers; negation, for example, simply involves interchanging 0's and 1's.

Many practical problems are essentially logical in form and could be solved by these methods. A simple example is that of finding the possible combinations of subjects which can be offered for an examination in which some of the subjects may be taken

4 N. Wiener, *Cybernetics* (Wiley, New York, 1948).

only in conjunction with certain others. In America, machines have already been used to solve problems arising from the complexity of insurance policies, and it seems certain that applications will soon be found in other fields.

Mechanical translation. A quite different application of digital computers is to the translation of articles of scientific interest. The number of technical papers published each year is continually increasing, and even the crudest translations will be welcome if they help the scientist to select the papers to which he ought to give his attention. According to one promising suggestion,[5] the machine is to be provided with two dictionaries: a stem-dictionary, containing the various word-stems and their English equivalents, and an ending-dictionary, to provide syntactical notes. In translating a passage the machine prints the English equivalents of the stem of each word together with syntactical notes taken from the ending-dictionary; and for this purpose the longest entry in the stem-dictionary which is part of a given word is to be its stem, while the remainder of the word is its ending. In the form stated, this method takes no account of idioms and other complicating factors, but many of these snags could be avoided by the use of a human pre-editor, who need know only the original language and whose task would be to eliminate possible sources of ambiguity from the text before it is fed to the machine.

One obstacle to mechanical translation is the time which a machine would require to search a dictionary of more than a few thousand words. Fortunately, scientists are content with using only a limited vocabulary of everyday words, and the difficulty could be overcome by combining a small basic dictionary with a dictionary of the relevant jargon. I say 'could', because so far very few practical experiments have been tried. This is to be expected, since the essential difficulty in mechanical translation is the immense complexity of language, and the small-scale experiments which have prefaced other applications of digital computers are in this case of much less interest.

Finally, a comment on the much-canvassed[6] question: Can computers be said to think? A straightforward negative answer is

5 W. N. Locke and A. D. Booth (ed.), *Machine Translation of Languages* (Chapman and Hall, 1955).

6 A. M. Turing, 'Computing machinery and intelligence', *Mind*, 59 (1950), pp. 433-460.

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not altogether satisfactory, because computing and playing games are activities which are usually regarded as requiring thought. Some writers interpret the question to mean, Could a machine be built which would be able to answer a succession of questions brought to it from someone in another room and to do this so convincingly that its interrogator would be left in doubt whether he had been questioning a man or a machine? Whatever the answer to this question, it seems clear that those who wish to attempt a definition of thought, or of life, must in future take into account the kind of machine activity we have just been discussing. But that is another story.

REVIEWS

VATICAN ASSIGNMENT. By Sir Alec Randall, K.C.M.G., O.B.E. (Heinemann; 21s.)

The author, until recently H.M. Ambassador to Denmark, offers this volume in all humility '. . . as an addition to the—I am told—approximately 230,000 books already written on Rome'. Like many of those books, it is based upon personal reminiscences; but it is outstanding amongst them for a happy combination of reasons. Principal of these is the fact that Sir Alec Randall's Vatican assignment was a diplomatic one, as Secretary to the British Legation during five eventful and crucial years from 1925 to 1930. Add to this an exceptional ability in lucid and colourful writing, a wide culture combined with a keen aesthetic appreciation, a nice sense of critical judgment, a marked vein of whimsical humour, and you have a most fascinating, informative, personal yet authentic inside story of a Catholic diplomat's Vatican contacts, official and unofficial, during a period covering such notable situations as the Portuguese *padroada* rights in Goa, the Strickland crisis in Malta, and the settlement of the 'Roman Question' with Mussolini. But besides the political involvements are delightful memories of audiences with the Holy Father arranged for visiting British V.I.P.s, vignettes of Vatican personalities, sidelights on official ceremonies, all interspersed with precious digressions and illuminating asides on history, art and culture. At the same time the author shows an understanding tolerance of the more childish customs and even superstitions of the Roman people, which it seems to him 'mere highbrow snobbery to despise'. The chapter on the working constitution of the Holy See, with valuable