A NOTE ON ELECTRIC AUTOMATIC COMPUTING MACHINES

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Although these devices are sometimes called "electronic" or "mechanical brains," they are designed for one specific purpose, the rapid performance of large pieces of numerical computation. To enable them to do this they are provided with a storage which holds numbers and instructions in a form suitable for triggering off various kinds of activities in the machine. The usual method is first to code the number or instruction as a row of 0's and 1's (by using binary instead of decimal notation in the case of numbers). A large number of stations, say a quarter of a million, are provided in the machine, each of which can be in one or other of two states, called "0" and "1," and a coded number or instruction is set up accordingly on a row of perhaps 40 of these stations. The earlier electronic machines, such as ENIAC, used a pair of radio valves for each station, but this led to a large expenditure of power in running the machine, and other methods have since been invented. The Manchester machine, referred to by Professor Jefferson in his Lister Oration, uses Professor Williams's storage, in which each station is a charged spot on the coating of a cathode-ray tube, large or small for 1 or 0. One tube holds about 2,500 spots. It is likely that all such machines will have a large magnetic storage as a secondary resource. This form of storage is very stable, and requires no power supply for its maintenance once the material is written in, but it is less accessible than electrical storage.

The machine operates by carrying out the instructions one after another, each instruction having some such form as "multiply this row by that row" or "copy this row into that." If it were necessary to put an instruction into the machine for each of the many millions of operations involved in a big computation it would obviously take as long to write in the instructions as to do the computations by hand. The feature that enables the machine, like a properly trained human computer, to work from a short table of instructions is its power of choosing which instruction to perform next, on the basis of the results of work already done, and hence to use the same instruction over and over again.

The speed of the machine is of the order of 1 millisecon. per elementary operation, a typical elementary operation being the addition or multiplication together of two numbers of 40 digits (in the scale of 2, =12 in the scale of 10). This is perhaps 10,000 times the speed of a human computer working with a desk calculating machine, without allowing for resting time.

This takes no account of the time required to get the problem coded for the machine, but it appears that this is a less formidable problem than was at first supposed, and may become very rapid when standard small routines have been worked out which can be tied together to make large ones. This is a matter on which a rapid increase of information may be hoped for now that machines are actually beginning to come into operation.

The variety of computing problems that can be handled by machines of this kind, by setting up a suitable table of instructions on them, is very great, including the approximate solution of partial differential equations, problems involving large integers (e.g., searching for primes), and questions in more abstract parts of mathematics. Indeed, convincing arguments have been given by Turing for the view that these are "universal" computing machines, in the sense that any well-defined piece of computation whatever could be done on them from a single table of instructions, given sufficient time and a large enough storage for numbers and instructions. In this they differ from such a machine as the ENIAC, which, though very flexible, is limited to a certain (large) repertory of possible assignments.

The expression "piece of computation" has a wider connotation than might at first be supposed, since many pieces of work which have at first sight nothing to do with arithmetic can be "coded" so as to consist of arithmetic operations. For example, the playing of a legally correct game of bridge, poker, or chess can certainly be so coded, and in this sense the machine could play these games. (Whether it could be made to play a good game is a different question.) It is no doubt the possibility of such non-mathematical applications that has led to these machines being brought into discussions on the thinking potentialities of machines, and to the suggestion that the human brain is itself a network of units of this general type. There is evidently a danger here that extravagant powers will be credited to these devices, and conclusions drawn too rapidly about biological analogues; but some caution is also necessary in coming to final conclusions in the opposite direction, on the basis of our knowledge of the behaviour of a small pilot model of this very new kind of machine, designed for a sharply limited purpose, which has been in rather halting action for a few months. The first question that will have to be asked is not "Can all kinds of thought, logical, poetical, reflective, be imitated by machines?" but "Can anything that can be called 'thought' be so imitated and, if so, how much?" The most promising line here will be to work within mathematics itself, to see how far the work of instruction-table making can be gradually transferred from the mathematician to the machine. The work of modern mathematical logicians gives us a good idea where the barrier is likely to be found, but this is too deep a question to pursue further in this note.

The "Mechanical Brain." The section on the left contains the control circuit, in the middle rack of which is a cathode-ray tube screen with (below) the control desk. The racks on the right-centre of the picture provide the "memory" section. Nearer the camera are racks for calculating circuits. The machine is "fed" at the control desk and the answer is read on the cathode-ray tube screen. For this illustration we are indebted to the Electrical Engineering Laboratories, Manchester University.