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"SIMPLE SIMON"

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A small mechanical brain that possesses the same fundamental characteristics as its larger relatives can explain in rudimentary fashion how they work

by Edmund C. Berkeley

DURING the past eight years the designers of computing machines have announced the completion of giant mechanical " brains" of increasing size and genius. Last spring a curious mutation in this evolutionary line was exhibited at Columbia University. It was the smallest complete mechanical brain.

Compared to its larger cousins the tiny computer was almost a moron. Like Simple Simon of the familiar nursery rhyme it entertained its audience with its rudimentary intellectual processes, and it was christened Simon. Simon occupies only a little more than a cubic foot of space, and it weighs a mere 39 pounds. In contrast to Aberdeen Proving Ground's great Electronic Numerical Integrator and Computer, or Eniac, which performs 5,000 operations a second, Simon performs one operation in about two thirds of a second. In contrast to Harvard University's Mark I calculator, which can remember 144 numbers at a time, Simon can remember 16 numbers at a time. In contrast to Bell Telephone Laboratories' two General Purpose Relay Calculators, which can conceive of 351,000,002 numbers, Simon can conceive of only four numbers. Yet Simon possesses the two unique properties that define any true mechanical brain: it can transfer information automatically from any one of its "registers" to any other, and it can perform reasoning operations of indefinite length.

How did Simon come to be built? What is its purpose? Can we expect this little moron of a mechanical brain to be useful around the laboratory and earn its keep?

THE STORY of Simon is closely connected to the story of the big mechanical brains. These machines fall into two main types: the "digital" and the "analogue." Digital means handling information as characters or digits, in the way the fingers of one hand can express the numbers 0, 1, 2, 3, 4, 5. Analogue means handling information as measurements of physical quantities; the measurements are analogous to numbers. There are no easy analogues for random numbers, alphabetical information and certain other classes of information. So digital computers are generally more versatile than analogue computers.

Both digital and analogue computers possess breath-taking powers. They can manipulate numbers much faster than the human brain, often 10,000 and sometimes 100,000 times faster. They are also more reliable than the human brain. As a result many problems that would not be practical for the human brain may be submitted to the machines.

Most of the digital machines are able to make choices and decisions. They can choose between numbers and between calculation routines. They can make choices from time to time in the course of a problem according to indications in the problem itself. Many of the machines can work out more than 95 per cent of their own instructions.

Powerful though the machines may be, there are difficulties in their application. It takes time, and often a long time, to train specialists to prepare the correct instruction sequences for a mechanical brain. It also takes time to train other specialists to operate the machine correctly, to use the right controls at the right time. And in spite of the fact that the machines are more reliable than human brains, they have temperaments and moods. They do not inevitably supply the correct answer, nor are they always consistent in their mistakes. Anyone who has sought to run a problem on such a machine has learned that it is vital to have good trouble-shooting—to find what part of the machine is failing to operate as it should, and then to repair or replace it promptly. Usually trouble-shooting on a big machine requires two people: a mathematician who knows what the instructions currently require from the machine, and an electrician who can get to the failing part of the machine and repair or replace it.

Unhappily it is difficult for an inexperienced mathematician or electrician to learn this job on the machine itself. It is too advanced to give much useful instruction to students; it is also too valuable to entrust to inexperienced hands. Its time is precious: it is monopolized by what some inhabitants of computing laboratories call VIPs—very important problems.

WHAT CAN be done about the difficulty? How can we provide training and experience for the few who must work with the big machines, and for the many who wish to understand them? We can hope that as time goes on the machines will become cheaper, less complicated, more easily operated and more accessible to students. Or we can build a really cheap, simple machine designed mainly to teach the student the fundamentals.

This we can do, provided we surrender one characteristic that is usually thought to be essential in computing machines: the capacity for useful work. Obviously this capacity is not required for teaching purposes. To abandon this capacity, in fact, is to give us some necessary freedom. We become free to play with the machine, and to tinker with it.

It was such considerations that led to the birth of Simon. But what sort of operations can a small, nonutilitarian mechanical brain accomplish?

In mathematics there exist not only systems that are very large, containing millions of numbers or elements, but also systems that are very small, containing only a few numbers or elements. In daily life we use some number systems that are very small. Take the days of the week: Sunday, Monday, Tuesday, Wednesday, Thursday, Friday, Saturday. This is exactly equivalent to a system of seven numbers: 0, 1, 2 ,3, 4, 5, 6. A smaller mathematical system in common use is right, left, up, down, back, front. This has six elements. A smaller one still is North, East, South, West. This has four elements. Perhaps the commonest and most useful of all mathematical systems has just two elements: yes and no. Mathematically we can use 1 and 0.

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Which of these small mathematical systems shall we choose for Simon? Let us choose a mathematical system of four elements. Then we can see at least a little of the numerical side of mathematics and still handle the logical side of yes and no.

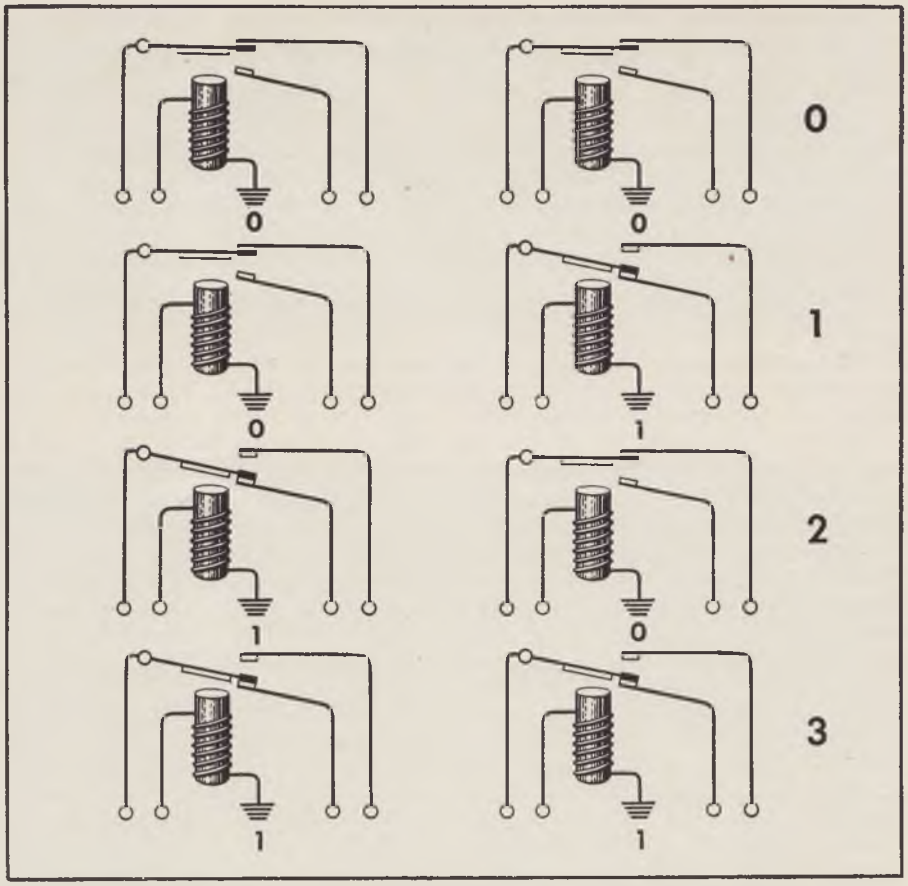
We can think of these four elements or numbers as four compass directions, North, East, South, West. Or we can think of them as four numbers, 0, 1, 2, 3. Or we can think of them in the notation of the scale of two—binary notation—in which they are written 00, 01, 10, 11. Here the left-hand digit counts not the number of tens but the number of twos, and the right-hand digit counts the number of ones. For example, 11 in binary notation means one two plus one one, and this in decimal notation is 3. Or we can think of these four numbers as right-angle turns: 0 for no turn, 1 for one right-angle turn; 2 for two right-angle turns in the same direction, and 3 for three right-angle turns in the same direction. With this kind of interpretation of 0, 1, 2, 3, we can see that 4 is interchangeable with 0, 5 with 1 and so on. If we turn through four right angles we face in just the same direction as before.

Now in order to make a computing machine, we must consider computing operations utilizing our numbers 0, 1, 2, 3. In the case of Simon it was decided to choose at least two computing operations belonging to logic. The two logical operations were "greater than" and "selection." These can be put in the following form. Greater than: Is the number *a* greater than the number *b*? Yes (1) or no (0). Selection: Choose the number *a* if there is an indication that *p* and *p* is 1, and choose the number *b* if there is an indication that *p* and *p* is 0.

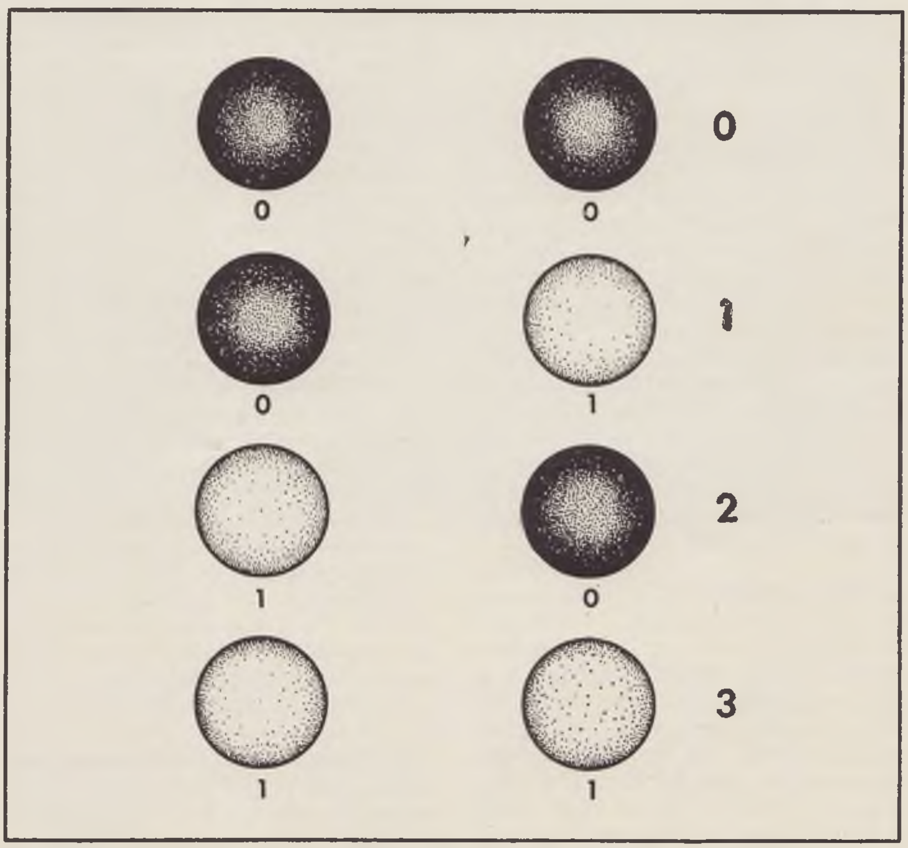
It was also decided to equip Simon with two arithmetical operations. The two operations which at once suggested themselves were addition and "negation." A mechanical adding system can be illustrated by the operation of an automobile speedometer. Each adding wheel in the speedometer proceeds 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 0, 1, 2 and so on. Simon, using only four symbols, adds units in this progression: 0, 1, 2, 3, 0, 1, 2, 3, 0, 1, 2, 3, 0 and so on. A man can add 1 and 2 and get 3; so can Simon. A man can add 2 and 2 and get 4, but when Simon adds 2 and 2 it gets 0; its limited mentality cannot distinguish 4 from 0.

Negation may be defined as "finding the negative of." In Simon we find the negative of a number by subtracting it from 0 or from 4, which is interchangeable with 0. Thus 0 is the negative of 0, 2 is the negative of 2, 1 is the negative of 3, and 3 is the negative of 1.

All these features of Simon were worked out some two years before Simon was actually built. Published as a chapter in the author's recent book *Giant*



RELAYS of Simon express numbers 0, 1, 2, 3. Each relay can express 1 or 0, and pairs of them can express numbers in binary notation. In this notation relays at left express number of twos; those at right, number of ones.



LIGHTS flash the answers of problems submitted to Simon. One pair of lights is sufficient to express Simon's four numbers in the binary notation. Simon has three other lights, however, for additional purposes (*see page 43*).

Brains, they served as an introduction to bigger computers. Even in the first hypothetical designs for Simon it was decided that its principal elements should be relays rather than electronic tubes. Circuits involving relays are considerably easier to understand than those involving tubes. In fact, they can be understood in terms of yes and no, *i.e.*, of current flowing and no current flowing.

A survey of war-surplus stores suggested that we use relays of 24 volts and 3,000 ohms, which were available at 60 cents each. A second-hand stepping switch was acquired and modified with coils that would energize at 24 volts. For feeding Simon its instructions, via a punched-paper tape, we chose the simplest available tape feed—a regular Western Union tape transmitter costing $50. A front panel with switches and lights, some rectifiers and condensers and a frame for mounting all the parts made Simon complete.

The machine is mounted on a chassis 24 inches long and 15 inches wide. Its front panel is 24 inches long and 6 inches high. The switches there enable the machine to be operated either automatically from tape or manually by pushing buttons. Simon shines its answers on the five lights that are mounted on the panel. Just behind the panel is the tape-feeding mechanism and the stepping switch. The rest of the machine consists mainly of 120-odd relays (of which about 10 per cent are spares, available for increasing Simon's capacity).

Simon was built by William A. Porter, a skilled technician who had a considerable responsibility in the construction of the Harvard Mark II and Mark III calculators, and two Columbia University graduate students of electrical engineering, Robert A. Jensen and Andrew Vall. Like any computer, Simon required three kinds of workers for its creation: a mathematician to design its circuits, an electrical engineer to make sure that all its elements would work, and a skillful technician to put it together. The final cost of Simon was about $270 for materials and another $270 for the labor of wiring. This figure does not include the cost of the designing and a good half of the labor, which was contributed.

THE OPERATIONS that Simon can perform with numbers are such as to make anyone present at the performance feel distinctly superior. Consider a typical problem, the first given to the machine, which embraces all the numbers and operations that Simon knows and demonstrates its capacities. The problem: Add 2 and 1; find the negative of 3; find whether the first result is greater than the second; if so, select 2; if not, select 3.

Simon, or for that matter any other mechanical brain, is analogous to a long series of sidings on a railroad. Freight cars may be switched onto the sidings and left there until they are brought out again. In a computing machine the freight cars are numbers or other items of information, and the sidings are called registers. Each register is fundamentally made up of two relays, although for practical reasons it may be made up of more (*see diagram at top of preceding page*).

Simon's 16 registers may store the numbers 00, 01, 10, 11, or the operations 00, 01, 10, 11. The first two registers (called Input Registers) take in from the punched tape either numbers or operations. The next six registers (called Storage Registers 1 to 6) store information unchanged until it is called for. The next five registers (called Computer Registers 1 to 5) have had mathematical and logical capacity wired into them in such a way that together they can compute. Computer Register 5 always holds the result of an operation, specified in Computer Register 4, on certain numbers specified in Computer Registers 1, 2 and 3. The last three registers of Simon (called Output Registers) are connected to five lights on the front panel, and whatever information they hold is spelled out by the lights.

As in any other mechanical brain, calculation in Simon proceeds as a series of commands. Each command to Simon takes the same form: "Take the number out of register____; put it into register____." The blanks may be filled with the numbers of registers in many ways. In fact, about 200 different commands of this kind can be given to Simon.

Let us now convert the first sentence of Simon's demonstration problem into a series of commands.

Operation: Take 2.

Command: Read from Input Register 1 (which has been filled from a line of punched tape holding the binary number 10) into Computer Register 1.

Operation: Take 1.

Command: Read from Input Register 1 (which has now been filled from another line of punched tape holding the binary number 01) into Computer Register 2.

Operation: Add.

Command: Read from Input Register 1 (now filled from another line of punched tape and holding the binary number 00, the symbol for addition) into Computer Register 4 (the register that holds the operation instruction).

Operation: Take the result and store it.

Command: Read from Computer Register 5 (now holding 11, the result of adding 10 and 01) into Storage Register 1.

This is the way Simon carries out a problem. The process may seem so simple as to lack meaning. Yet the machine is required to remember results from the earlier stages of the problem, to refer to these results and to combine them. Simon actually has a slightly better memory than many human beings. Its memory capacity is the equivalent of a sheet of paper where 16 numbers can be put down and referred to later.

WE have now described how Simon came to be conceived, how Simon was built and what sort of problems Simon can do. But this is not the end of Simon's story. The little machine has some interesting future possibilities.

The first is that Simon itself can grow. It possesses all the essentials of a mechanical brain, but other circuits can be added to it. One that can easily be added is a "carry" circuit. There is no basic reason why Simon should be restricted to numbers less than 4. A carry circuit will enable Simon to deal with numbers of two digits. Another possible extension of Simon would be to add a mechanism capable of punching paper tape. Then impulses delivered by Simon could be used to punch the tape, and Simon could prepare some of its own tapes. It would not be surprising if in another six or eight months Simon was able to handle decimal digits, and to do a moderate amount of real computing.

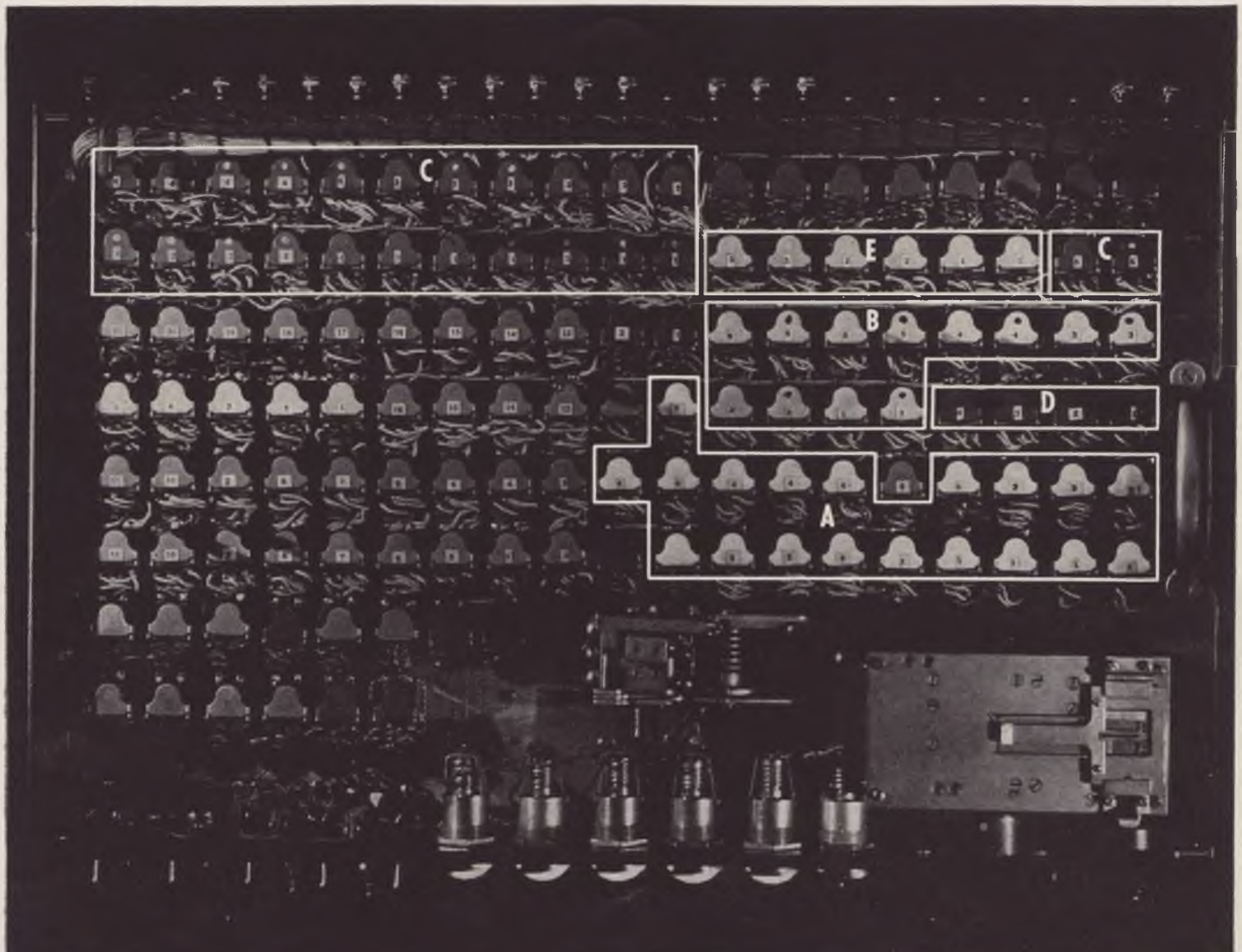
Simon has a second future: It is likely to stimulate the building of other small mechanical brains. Perhaps the simplicity and relatively low cost of such machines may make them as attractive to amateurs as the radio set and the small telescope.

Simon has a third future: It may stimulate thought and discussion on the philosophical and social implications of machines that handle information. An essential point about these machines is that they are endowed with the spark of automatic activity. In a machine this is basically the capacity to pay attention to and respond to a series of stimuli. The more experience human beings have with this unique faculty, the better they will be able to develop and utilize it.

SOME DAY we may even have small computers in our homes, drawing their energy from electric-power lines like refrigerators or radios. These little robots may be slow, but they will think and act tirelessly. They may recall facts for us that we would have trouble remembering. They may calculate accounts and income taxes. Schoolboys with homework may seek their help. They may even run through and list combinations of possibilities that we need to consider in making important decisions. We may find the future full of small mechanical brains working about us.

Edmund C. Berkeley is the author of the recent book Giant Brains.

FRONT VIEW of Simon shows its controls and lights. Here the lights show not the answer to a problem but the stage of its solution. Light at right indicates power is on. Other two lights show that problem is at stage 9.



TOP VIEW of Simon shows its relays. Their basic functions are programming (A), storage (B), computation (C), input (D) and output (E). At the lower right is the tape feed. To the left of it is the stepping switch.

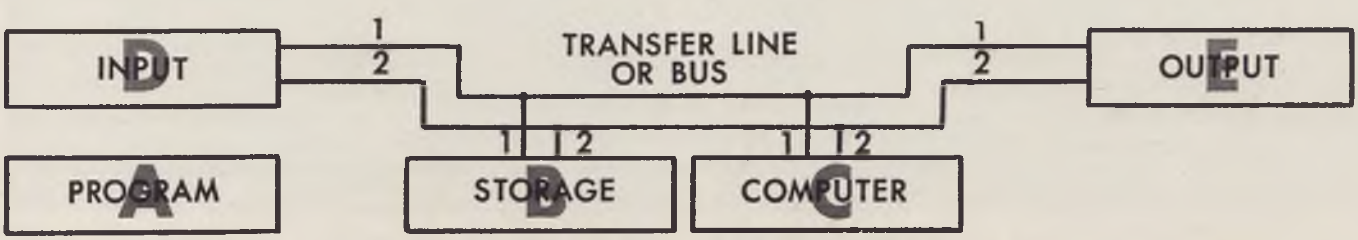


DIAGRAM shows relationship of relays noted on photograph above. The remaining relays are for auxiliary purposes or for expanding the capacity of Simon. By adding a "carry" circuit, Simon will be able to count higher.