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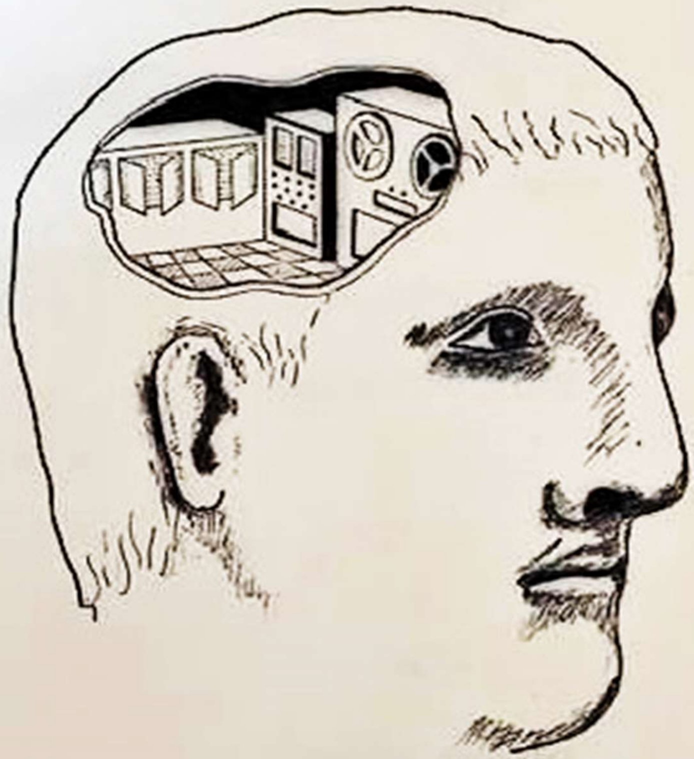

THE COMPUTER MAN'S NEW BRAIN

by: B. PARHAMI

ELS Language Center

May, 1969

The Computer

Man's New Brain

By:

Behrooz Parhami

To my Father,

my Mother,

and my dear Sisters

PREFACE

In popular accounts, computers are often described as "giant brains," "electronic brains," or "thinking machines." The object of this paper is to demonstrate the extent to which the above descriptions are true by comparing the structure of the brain and that of a computer, and by studying some thinking operations which have been performed by computers.

I should like to express my deep gratitude to my dear teacher, Mr. Hackett, whose useful comments helped me in writing this paper.

Behrooz Parhami

May, 1969

Most people nowadays have heard of computers which are often described as electronic brains. They are becoming of great importance, so much so that the tide of change which they constitute is often spoken of as the Second Industrial Revolution. For it is compared with the First Industrial Revolution, which began in England in 1760, and consisted of adding inanimate energy such as steam and electricity to the muscles of men. In a similar way the inanimate powers of the new automatic computers add to the brains and minds of men.

In studying the history of computers, we can see that one of the earliest ideas dates back to 1642, when Pascal used a number wheel and ratchet combination as an aid in his father's computations. In 1694, Leibnitz demonstrated a machine which could multiply as well as add. However, there was no important development until the nineteenth century.

In 1813, Charles Babbage had his first idea for a computing machine which he called the Difference Engine. He succeeded in obtaining official support from the British Government in 1823. However, in 1833, after the Government had spent £17,000 on the Difference Engine, the work was stopped because of engineering difficulties. Then Babbage had a new idea for a machine which he called an Analytical Engine. The Analytical Engine was never built because the engineering technique was not at that time equal to the demands that the construction of Babbage's machine made on it.

In 1937, it occurred to Howard H. Aiken that the components and techniques developed in punch-card machines would enable a completely automatic computer to be built. He therefore approached the International Business Machines Corporation (IBM) and as a result the Automatic Sequence Controlled Calculator was formally presented to Harvard University by the Corporation on 7th August, 1944.

The first electronic calculating machine to be built was the ENIAC*, which was designed by J. Presper Eckert and John W. Mauchly. It was built in the Moore School of Electrical Engineering, University of Pennsylvania, and was completed in the summer of 1946. Since that time a great number of electronic computers have been constructed by various companies. In the course of development up to now, electromechanical relays, vacuum tubes, crystal diodes, ferromagnetic cores, and transistors have been successively used giving rise to as many different kinds of computers.

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*ENIAC is an abbreviation for Electronic Numerical Integrator and Computer.

Before considering the structure of the brain and the process of thinking, it seems necessary to give a clear definition for the brain:

> "The brain is that organ of the body which processes information received from a relatively stable environment (including the body itself) in order to secure successful behaviour of the organism in relation to its environment." *

The kind of information refered to above enables the brain to distinguish between an open door and a closed one, so that in one case we walk through, and in the other we stop before bumping our noses.

The brain is the continuation of the spinal cord. The older portion, the brain stem, is similar to the cord in appearance, though of larger bulk and more irregular contour. The brain stem consists of three main divisions; the hindbrain, midbrain, and forebrain. When the brain is fully formed, two large regions have been added. The cerebellum grows out of the hindbrain, and the cerebral hemispheres grow out of the forebrain. Figure 1 shows a diagram of the brain cut in half down its midline.**

The brain is connected to a great many structures in other parts of the body through the fibers of the twelve cranial nerve

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*Mortimer Taube. Computers and Common Sense (New York: Columbia University Press, 1961), p. 71.

**Elbert Tokay, Ph. D. Fundamentals of Physiology (New York Barnes & Noble, Inc., 1968), p. 180.

Of these twelve cranial nerves, three are almost entirely sensory in function and bring information from various organs to the brain. Six of them are purely motor nerves, through which the brain controls the movements of various parts of the body. The remaining three nerves consist of both sensory and motor fibers.

Injuries to brains have shown that each part of the brain has certain duties. For example, there is a part of the brain where impressions are recorded and compared. If an accident damages the part of the brain where certain information is stored, the human being has to relearn the information destroyed

Thinking in the human brain is done essentially by a process of learning and remembering. We store the information that 2 and 3 are 5, and store it in such a way that we can give the answer when questioned. But we do not know the location of the register* where this particular information is stored. Nor do we know how we are able automatically to select the nerve channels that lead into this particular register, get the answer and report it.

The process of thinking in the human brain is very similar to information processing in computers. We will describe the similarities but before that we must know what a computer is and how it can do certain thinking operations.

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*A "register" is a device or an element capable of retaining information, often that contained in a small subset (e.g. one word) of the aggregate information.

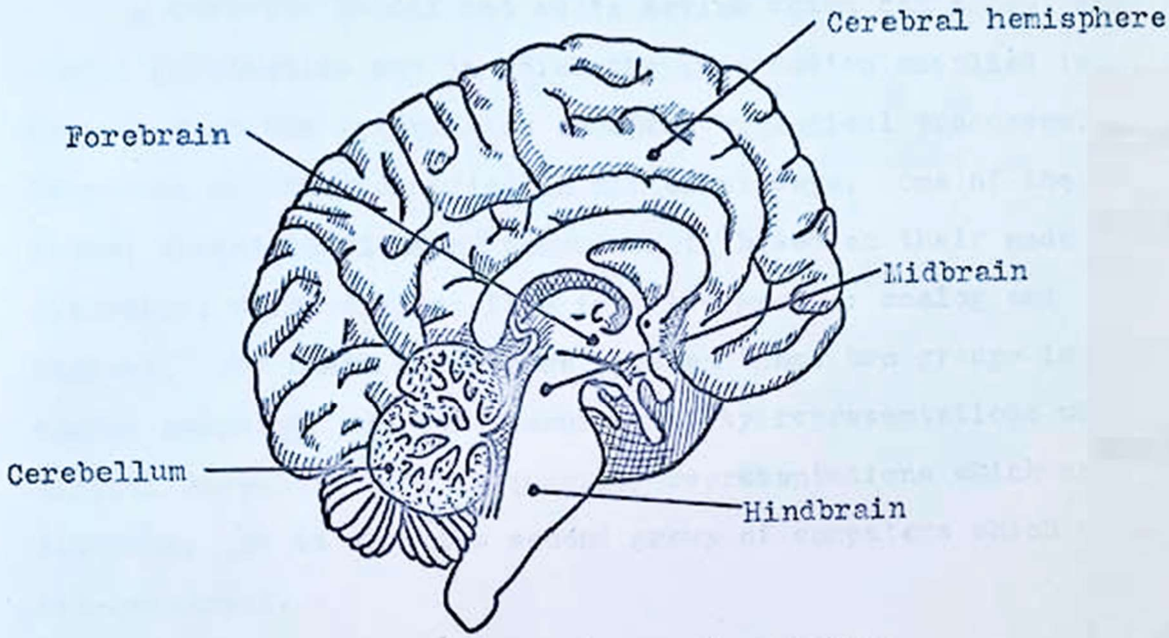

Figure 1- The brain cut down the midline.

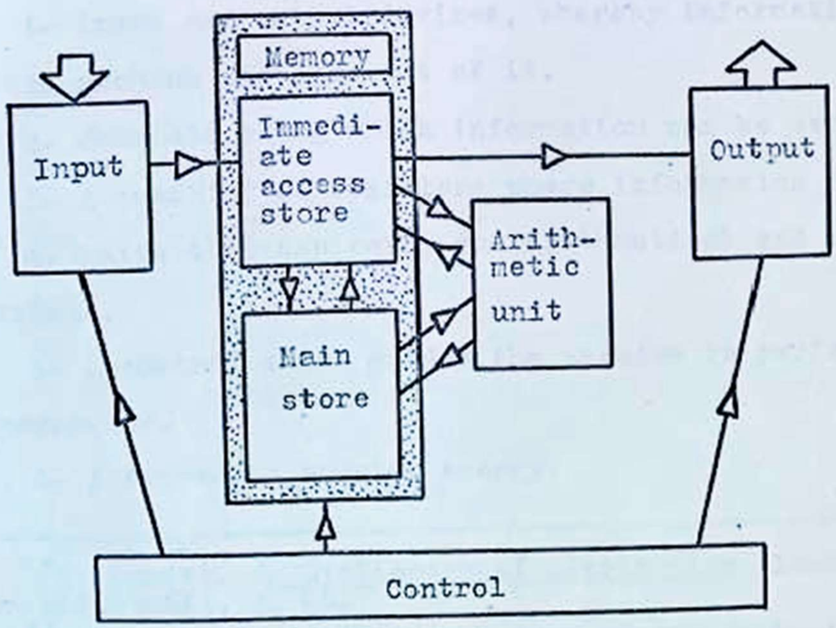

Figure 2- Simplified diagram of a digital computer.

A computer is defined as "a device which can accept and supply information and in which the information supplied is derived from the information accepted by logical processes."* Computers may be classified in different ways. One of the most common classifications of computers is based on their mode of operation, which divides them into two groups: analog and digital. The basic difference between these two groups is that analog computers use continuous quantity representations while digital computers deal in quantity representations which are discrete. It is with the second group of computers which we are concerned.

In general, a digital computer consists of the following parts:**

1- Input and output devices, whereby information can go into the machine and come out of it.

2- Channels along which information can be sent.

3- A quantity of registers where information can be stored.

4- Units that can carry out arithmetical and logical operations.

5- A control which guides the machine to perform a sequenc of operations.

6- A source to provide energy.

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*S. Handel. A Dictionary of Electronics (London: Penguin Books Ltd, 1964), p. 65.

**Edmund Callis Berkeley. Giant Brains or Machines That Think (New York: John Wiley & Sons, Inc., 1949), p. 7.

A simplified diagram of the elements of a digital computer is presented in figure 2.*

For an automatic computer to solve a problem it is first necessary that human beings think out a way of solving the problem, and then instruct the computer in how to solve the problem when given the data. The human operation of instructing the automatic computer is called "programing," and the resulting set of instructions is called a "program." If we put a program into an automatic computer and press the "start" button, it will print out the answers as it obtains them.

Automatic computers can do several things and cannot do some others.** They can:

1- Add, subtract, multiply, and divide.

2- Do some logic operations.

3- Choose among alternatives in a manner that amounts to making a decision.

4- Remember and recall.

5- Communicate with their operators and with other machine

6- Direct themselves in a predetermined manner.

7- Check on their own accuracy in one or more of several ways.

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*S. Handel. A Dictionary of Electronics. (London: Penguin Books Ltd, 1964), p. 65.

**Ned Chapin. An Introduction to Automatic Computers (Princeton, New Jersey: D. Van Nostrand Company, Inc., 1957), pp. 13-18.

They cannot:

1- Process the data of an application for which they have not been programed.

2- Make a nonpredetermined decision.

3- Completely avoid making errors.

4- Construct their own programs, at least not as yet.

In popular accounts, automatic computers are frequently described as thinking machines. An attempt to discuss whether or not machines can think encounters the difficulty of giving a satisfactory definition for the meaning of the word "think." Different people will define "thinking" in different ways. Some writers have insisted that the power to store information and to perform operations of a conditional nature are sufficient to constitute thinking. Some others have argued that "thinking" is a word which can be used only for a human being, and that no action of a machine, however remarkable, should be called thinking.

There is no doubt at all that up until the time when machines began to do reading, writing, arithmetic, reasoning, and looking up data in records, all these activities would have been classified as "thinking." If a dog or chimpanzee or other animal had ever done these things, the animal would have been classified as "thinking."

In 1939, Turing suggested that one might avoid this linguistic difficulty by asking instead, whether a machine could impersonate a human being. He proposed the following experiment commonly called the "Turing test" :

> "A machine could be said to be capable of thinking if it could carry on a conversation with a human being, located in another room, in such a way that the human being could not tell if he were conversing with a machine or with another human being." *

A second part of the argument concerning whether or not machines can think is based on the comparison of a list of operations that may be called "thinking" when performed by an educated human being, to the similar operations when performed by a programed computer. Let us contrast briefly the human being and the computer:

Operations by human beings	Operations by computers
Reading	Taking in information
Writing	Putting out information
Arithmetic, Mathematics	Arithmetical unit of the computer
History, Geography, Literature, Social Studies, etc.	Storage of certain information in the memory units of the computer.
Foreign Languages	Machine translation from one language to another

This evidence shows how remarkable is the extent to which thinking operations of human beings can be performed by a computer.

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*Edmund C. Berkeley. The Computer Revolution (Garden City, New York: Doubleday & Company, Inc., 1962), p. 88.

Is there any human thinking operation inherently beyond the capacity of computers? The answer is "No" if human beings understand that operation well enough so that it can be program for a computer. Even in the case where the operation is not understood that well, there is some evidence that a computer can be programed to perform it. For example, a learning machin that was presented in 1961, learns by trial and error.* It relates new situations to past experience and continually improves its skill, receiving only signals "right" or "wrong" from its human teacher.

On the whole, we can say that the differences between human beings and machines are differences of degree rather than quality. Only those thinking operations which are not well understood, and which therefore cannot be explained precisely, may perhaps be beyond the limit of what is programable on a computer.

Take the fairly simple case of the recognition of a friend's face.** John can recognize the face of his friend Robert, from among thousands of other people, even if Robert's face contains no particular distinguishing marks. But it is hard to imagine how a computer could be programed to recognize the face of Robert when given thousands of pictures. One of

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*This machine which was called the "Cybertron" was develop by a division of the Raytheon Company in Norwood, Massachusetts.

**Edmund C. Berkeley. The Computer Revolution (Garden City New York: Doubleday & Company, Inc., 1962), pp. 25-26.

the basic reasons for the difficulty in programing the computer is that John cannot explain exactly what methods he uses for recognizing the face of Robert. It is conceivable that John actually uses not only details of Robert's face, but also details of context and surroundings--so that if Robert were dressed in unusual clothes and were encountered walking along a street in a strange city, John would not recognize him.

Through the next pages we will study some thinking operations which are already well enough understood to be carried out by a computer, and we will see that the more deeply we understand a thinking operation, the better it can be carried out by a computer.

A favorite area of research in artificial intelligence is in computer programs that play games. Game playing has many fascinating aspects to the researcher. It provides a direct contest between man's wit and the machine's wit. The game of chess is one of man's valued intellectual diversions, and a number of chess playing programs have been constructed.

How can we construct a program for a digital computer to play chess? It is obvious that chess is a finite game and there is only a finite number of positions, each of which admits a finite number of alternatives. We can be sure that any chess game will terminate and a position will be reached that is a win, loss, or draw. Thus chess can be completely described as a branching tree (as in figure 3), the nodes corresponding to positions and the branches corresponding to the alternative moves from each position. In terminal positions: (+) means a win for White, (0) means a draw, and (-) means a loss for White.

It is clear that for a player who can view the entire tree and see all the ultimate consequences of each of the alternatives chess becomes a simple game. Starting from terminal positions he can work backwards, determining at each node which branch is best for him or his opponent until he arrives at the alternative for his next move. This inferential procedure is called "minimaxing" in the theory of games.

Minimaxing might have been the principle on which chess playing programs were based if the tree were not so large. Even current computers can discover only a very small fraction of it in years of computing. There are something like 10^{120} continuations to be explored, with less than 10^{16} microseconds available in a century to explore them.*

Humans play chess, and when they do they engage in a behaviour that seems extremely complex. Consider, for example, a part of a player's (White's) running comment as he analyzes the position in figure 4:

> ".... Are there any other threats? Black also has a threat of Knight to Bishop 5

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*Edward A. Feigenbaum & Julian Feldman. Computers and Thought (New York: McGraw-Hill Book Company, Inc., 1963), p. 43.

threatening the Queen, and also putting
more pressure on the King's side because
his Queen's Bishop can come over after he
moves his Knight at Queen 2; however,
that is not the immediate threat.
Otherwise his Pawn at King 4 is threatening
my Pawn...." *

Note that his analysis is qualitative and functional. He makes evaluations in terms of pressures and immediacies of threat, and gradually creates order out of the situation.

Let us consider a program known as the "NSS Chess Program," which was suggested in 1958 by Newell, Shaw, and Simon.** This program has a set of goals, each of which corresponds to some feature of the chess situation--King safety, material balance, center control, development, King-side attack, and promotion. The goals are independent, so that any of them can be added to the program or removed without affecting the remaining goals.

Each goal has associated with it a collection of processes: A move generator, a static evaluation routine, and a move generator for analysis. The move generator associated with each goal proposes alternative moves related to that goal. Each move proposed by a move generator is assigned a value by an analysis procedure. The value assigned to a move is obtained from a series of evaluations, one for each goal.

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*Edward A. Feigenbaum & Julian Feldman. Computers and Thought (New York: McGraw-Hill Book Company, Inc., 1963), p. 40.

**pp. 50-70 of the above mentioned book.

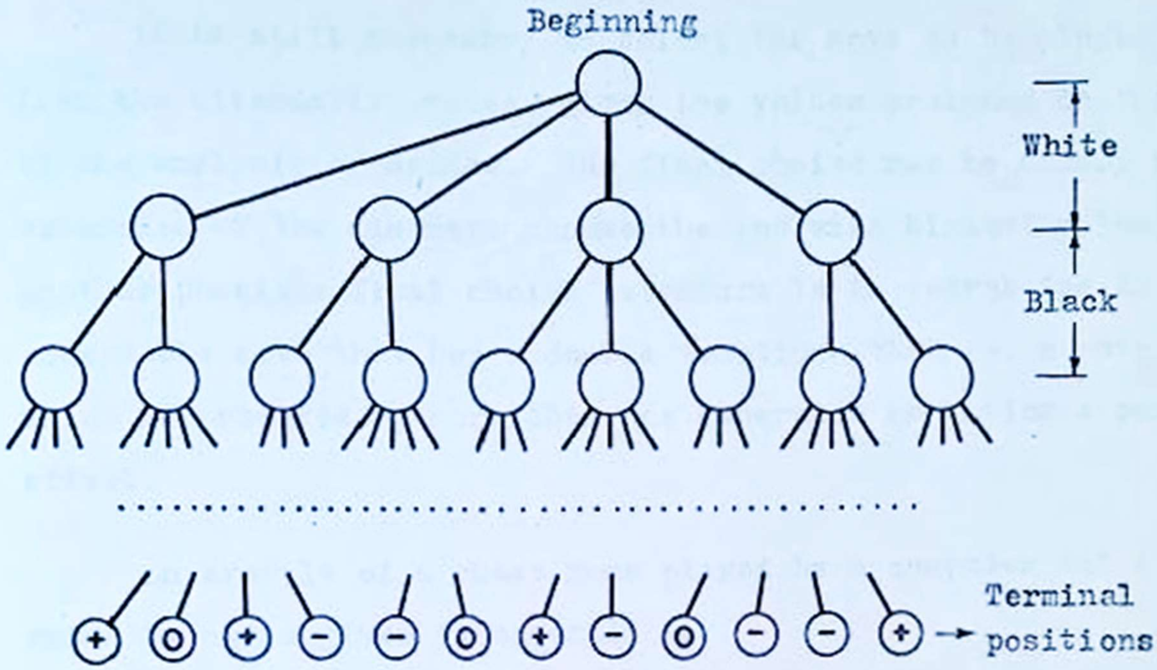

Figure 3- Chess can be described as a branching tree.

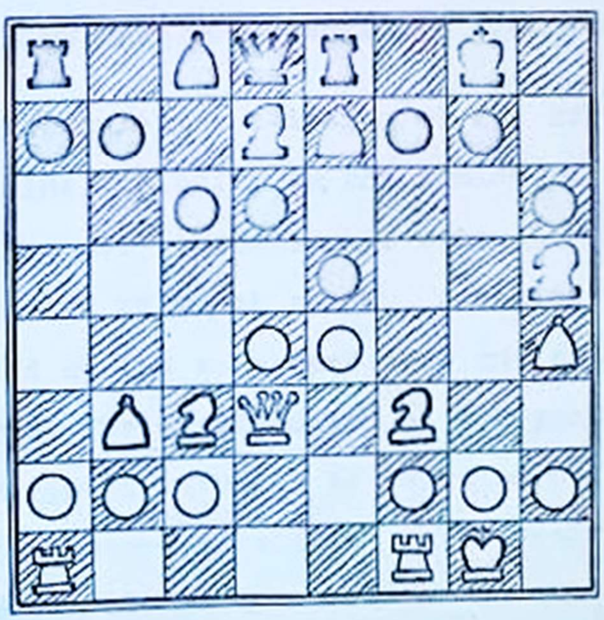

Figure 4

It is still necessary to select the move to be played from the alternative moves, given the values assigned to them by the analysis procedure. The final choice may be simply an extension of the minimax: choose the one with highest value. Another possible final choice procedure is to search for an acceptable move that has a double function--that is, a move which is proposed by more than one generator as having a positive effect.

An example of a chess game played by a computer and a human being is given in appendix A.

Now, let us consider another thinking operation which has been performed by automatic computers: translating from one language to another.* The first successful trial occured in 1954, when the IBM Type 701 translated from Russian to English.

A total vocabulary consisting of 250 Russian words (in latinized spelling) relating to the fields of politics, law, mathematics, chemistry, metallurgy, communications, and military affairs was punched on punch cards. Associated with each Russian word and punched on the same card were one or two English equivalent words. The construction of the program allowed different meanings of words to be selected and the order of words could be left unchanged or altered. The program consisted of about 2400 program steps.

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*Edmund Callis Berkeley. Computers, Their Operation and Applications (New York: Reinhold Publishing Corporation, 1956), pp. 296-297.

With about 5 to 8 seconds for each translation of each sentence, the machine produced translations such as the following

KACHYESTVO UGLYA OPRYEDYELYAYETSYA KALORYIYNOSTJYU
The quality of coal is determined by calorie content.

MI PYERYEDAYEM MI SLYI POSRYEDSTVOM RYECHYI
We transmit thoughts by means of speech.

There is still a long way to go, but the possibility of effective linguistic translation by automatic computers has been definitely demonstrated.

Now, let us consider another favorite area of research in artificial intelligence: conversation with a computer. Of all the areas of application of computers to human affairs, one that is very likely to have the most far reaching affects is that in which computers converse and discuss with human beings, using ordinary language and handling ideas appropriately. In order not to be misunderstood, we must make clear that here "discuss and converse" means in writing. In other words, both the human being and the computer exchange messages in writing. Conversation and discussion by voice is, of course, not impossible, but it is much further in the future than discussion using typed characters.

The question of conversation with a computer has a key interest because of Turing's definition of a thinking computer mentioned in page 9. Since that time, this definition has stood as a challenge to computer people. About 1954 John W. Carr III, who was giving a course on computers for students at the

University of Michigan, assigned to his students the problem of programing a computer to carry on a conversation about the weather. But no student took up the challenge. In December of 1958, it was decided to work out in detail a version of this problem and to try to persuade some computer center to run the problem on a computer.

To begin programing a computer to converse about the weather, we may classify words into three types: ordinary words, time words, and operator words.* Ordinary words are those which have meanings even when isolated from context; such as "snow." Time words describe times of the year or a time relation to the present; such as "October," and "last week." Operator words have no meaning when separated, but when taken in their context they alter the meaning of other words. Thus they have a functio rather than a meaning. For example, the word "not" by itself is meaningless, but in the statement "The sun is not shining," its function is to change the meaning of its neighbors.

Let us first discuss the representation of meaning in the computer program.. The meaning of an ordinary word is represente by a number pair (d,q). The second number of the pair, q, names the quality implicit in the meaning of the word. The first number, d, gives a quantitative description of the quality q; that is, d is the degree of the quality q. For example, words

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*Edmund C. Berkeley. The Computer Revolution (Garden City New York: Doubleday & Company, Inc., 1962), pp. 94-96.

describing wet weather are represented as:

dew	(1,1)
drizzle	(3,1)
rain	(6,1)
cats and dogs	(7,1)
downpour	(9,1)

A meaningless word is represented by the pair (0,0).

Similarly the sense of a time word is represented by the pair (d,t), where t gives the type of time, calendar or relative and d again gives the degree. For example:

yesterday	(1,10)
today	(2,10)
tomorrow	(3,10)
December	(1,9)
January	(2,9)
February	(3,9)

The function of an operator word is also symbolized by a two number pair, (d,f). Here f designates the function to be carried out, and d the degree to which the function f must be executed. Examples of operators which negate words preceding them in a context are:

change	(1,13)
abate	(2,13)
stop	(3,13)

Now, let us work through a typical example.* Suppose the following remark is made to the computer:

"I do not enjoy rain during July."

The computer substitutes the numerical representations for each

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*Edmund C. Berkeley. The Computer Revolution (Garden City New York: Doubleday & Company, Inc., 1962), pp. 97-99.

of these words as the remark is read in. The resulting sentence then appears inside the computer as:

(0,0) (0,0) (3,14) (3,11) (6,1) (0,0) (8,9)

The function of (3,14) is carried out on (3,11) making it into the new word (3,12), "dislike," and changing the operator word's representation to (0,0):

(3,14) not	(3,11) enjoy	⟶	(0,0) ---	(3,12) dislike

The meaning of the remark is now said to be the set of non-zero pairs:

(3,12) (6,1) (8,9)

This combination of qualities in the original remark causes the program to compute the degree of interaction between the weather mentioned in the statement:

rain	(6,1)

and the weather associated with the month of July:

heat	(7,5)
blue skies	(6,3)

It finds that the two sets of weather parameters are in essential disagreement.

Now the program must choose a reply frame. It notes that the original remark is characterized by:

weather	(rain)
emotion	(dislike)
calendar time	(July)
statement	(period, not question mark)

and that the interaction gave a result of disagreement. In the computer's memory there is a reply frame corresponding to this particular combination of qualities and interactions. The program then selects a frame which happens to be this:

"Well, we don't usually have ____ weather in ____, so you will probably not be disappointed."

This contains two blanks. The program then proceeds to fill in the blanks with words originating from the remark, environment, or machine's preferences. In this case the reply would then be:

"Well, we don't usually have rainy weather in July, so you will probably not be disappointed."

More examples on conversation with computers are given in appendix B.

In the preceding pages, we have described the structure of the brain and that of a computer briefly, and we studied some thinking operations which have been performed by computers. Now, we want to compare the computer to the brain and give a final answer to the question of whether or not a computer can think.

The human thinking system consists of elements which are similar to those of a digital computer, mentioned in page 6. The function of sensory organs in the body is exactly the same as that of the input device of a computer. The output device of a human being is his ability to speak and write. The nervous system of the body forms the channels along which information can be sent to the brain. This information is sent in the form of electric impulses, in just the same way as in a computer. The brain itself functions as the control, memory, and arithmetical unit of a computer. The function of a vacuum tube or a transistor in a computer is the same as that of a neuron in the human brain.

Of course the complexity and efficiency of the brain is much greater than that of a computer.* An aspect of the brain's greater complexity is the great size of its memory capacity. A large modern computer has a memory capacity of several million bits. The memory capacity of human brain has been estimated at several billion billion bits. So the brain's memory capacity is about 100,000 billion times as great as that of any existing machine.

We can use as an index of relative efficiency the ratio of the number of unit actions that can be performed by equal volume of each in equal times. A neuron is about one billion times smaller than the basic unit of a computer, and it is about 100 thousand times slower in its action. Dividing these two figures gives us the desired index: the brain is about 10 thousand times more efficient than a computer.

Although the complexity and efficiency of a computer is much less than that of the human brain, and in spite of the fact

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*Irving Adler. Thinking Machines (New York: The John Day Company, 1961), pp. 182-183.

that it cannot do intuitive thinking, make bright guesses, and interpret complex situations, it can replace the brain in certain fields. A computer does not need to come anywhere near to passing Turing's test* in order to be useful. However, science and technology is developing so fast that it is not impossible, though hard to imagine, a machine which can pass the test in the near future.

The answer to the question of whether or not a computer can think depends, as we mentioned before, on the definition of "thinking." The answer is "no" if we define thinking as an activity peculiarly and exclusively human. The answer is "yes" if we admit that the question is to be answered by experiment and observation, comparing the behaviour of the computer with that behaviour of human beings to which the term "thinking" is generally applied.

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*For explanation of Turing's test see page 9.

Appendix- A

A Chess Game Played by a Computer Program*

The following chess game was played by the NSS chess program, CP-I. Its opponent was Prof. H. A. Simon, playing black CP-I played white. The program was run on JOHNNIAC, and the moves each took 2 to 50 minutes of processing. The program had three goals: material balance, center control, and development. The lack of goals corresponding to king safety, serious threats, or pawn promotion seriously unbalances the play and makes the program insensitive to certain aspects of the play.

	CP-I	H. A. Simon
1	P-Q4	N-KB3
2	N-QB3	P-Q4
3	Q-Q3?	P-QN3
4	P-K4	B-N2
5	PxP	NxP
6	N-B3	P-K3
7	B-K2	B-K2
8	B-K3	0-0
9	0-0	N-Q2
10	KR-K1	P-QB4
11	QR-Q1	Q-B2
12	NxN	BxN?
13	P-QR4?	QR-B1
14	Q-B3	B-KB3!
15	B-QN5	BxN
16	PxB	KR-Q1
17	BxN?	QxB
18	P-N3	PxP
19	Q-Q2!	Q-B3!
20	B-B4	QxQBP
21	QxQ	RxQ
22	R-QB1	KR-QB1
23	QR-Q1	KR-B6
24	P-N4	KRxP
25	B-N3	P-Q6
26	R-QB1	B-N4
27	RxR	PxR
28	B-K5	P-B8=Q
29	RxQ	BxR
30	Resigns	

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*Edmund A. Feigenbaum & Julian Feldman. Computers and Thought (New York: McGraw-Hill Book Company, Inc., 1963), pp. 66-70.

Appendix- B

More Examples on Conversation With Computers*

Below are three comments made concerning the topic of weather. Following each of these comments are a group of ten replies, one of which was made by the IBM 704 Computer at M.I.T. The nine other replies were made by human beings. The reason of putting these replies together was to know if one can distinguis the Computer's reply.

A- Would you mind if we had cloudy and windy weather now?

1-Natch!
2-Yes.
3-Yes, I certainly would.
4-I like windy weather.
5-No.
6-I might mind, but I couldn't prevent it.
7-Rather not.
8-I usually do not mind windy weather if it is not too persistent.
9-Not after all this heat.
10-Any kind of weather in this region is bad.

B- I have never seen it so hot!

1-Oh, don't be such a sissy.
2-You probably have, but don't remember.
3-I'm sure I say this several times a year.
4-Nor have I. But it does not bother me.
5-Good day for a tan.
6-Because it's my vacation.
7-Turn around.
8-You haven't been to Madrid lately, have you?
9-Almost as bad as the Sahara on my last trip.
10-You're exaggerating.

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*Edmund C. Berkeley. The Computer Revolution (Garden City New York: Doubleday & Company, Inc., 1962), pp. 203-210.

C- What kind of weather do you want this spring?

1-I would like warm, sunny days, but what I want and what we're likely to get are quite different.
2-Fair and cool.
3-Warm, sunny days.
4-In May I like nothing better than a full day of sunshine and an evening shower.
5-Hot!
6-I hope it showers.
7-Warm.
8-Mild weather--the milder the better.
9-Spring? I thought we just had spring.
10-Warm.

The replies to above mentioned comments which were made by the IBM 704 Computer are respectively numbers 8, 1, and 4.

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