BASIC COMPUTER ORGANIZATION

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OUTLINES

I. Introduction

A digital computer is a machine that is able to execute a set of instructions given to it in order to solve a given problem. This set of instructions is called program and each computer only recognizes a limited set of instructions.[1] In order to show how a digital computer works imagine the following situation[2]: a person, who is referred as an operator was taught to execute his job by carring out a given set of instructions. For each instruction is defined a fixed action which has to be always done in the same way. The operator is not allowed to modify the actions that one associated with the instructions. He receives the instructions, i.e.,the description of his task, from other person, probably his boss, and has the following resources available:

1. A box, called INPUT, which is used to hold cards containing numeric values.
2. A typewriter
3. A calculator able to perform the basic arithmetic operations such as addition , subtraction, multiplication and division.
4. A set of frames. Each frame can be empty or contain a card with an instruction or a value. Each frame has a label with a number to provide identification facility.
5. A pencil and blank cards.

The function of the operator is to pick up a card with an instruction from a given frame, to interpret it and then to execute the action associated to it. After that, he

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1 Tanenbaum, Andrew, <u>Structured Computer Organization</u>, p.1

2 Paula Filho,Wilson, Personal Communication (classes)

must pick up the next instruction in the following frame unless the previous instruction has driven him to a specific frame. Furthemore, the operator always begins the execution of his task by examining the card in frame number 1. Therefore , the instructions describing the service to be done are passed to the operator by putting them into the frames.One instruction for each frame and the first instruction must always be in frame number 1.

The followings are the possible instructions the operator can receive[3,4].

1. READ TO FRAME X

   Explanation: The operator must take the first card from the input and then put it in the frame whose number(x) is given in the instruction.For example, READ TO FRAME 30 means that the card from the input box has to be moved to frame number 30.

2. WRITE FROM FRAME X

   Explanation:The operator must typewrite the value which is written on the card placed into frame number x. For example,WRITE FROM FRAME 30 means that the value on the card in frame number 30 must printed by using the typewriter.

3. ADD FRAME X TO FRAME Y

   Explanation: The operator must perform the addition of the numbers that are specified by the cards in frames x and y. For instance,ADD FRAME 30 TO FRAME 50 means that the value on the card in frame 30 must be added to the value on the card in frame 50.

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3. Mano,M.M, Computer System Organization, p. 255
4. Intel Microcomputers:8080 Microcompsuter Systems,p. 4-1

Obviously the arithmetic operation is done by using the available calculator.

4. SUBTRACT FRAME X FROM Y

   Explanation: Similar to ADD but now the operation is the subtraction.

5. MULTIPLY FRAME X BY FRAME Y

   Explanation: Similar to ADD but the operation is the multiplication.

6. DIVIDE FRAME X BY FRAME Y

   Explanation: Similar to ADD but the operation is the division.

7. STORE INTO FRAME X

   Explanation : Once the result of the operations that are done by using the calculator is not automatically copied into a card by the operator , it can be lost if another operation is performed,so, this instruction is used to remind the operator to copy the result in the calculator on a blank card and put it into the frame specified by the instruction. If the frame has already a card,the previous card is replaced by the new one.

8. GOTO FRAME X

   Explanation: This instruction tells the operator to pick up the next instruction in frame x instead of the following one.

9. GOTO FRAME X IF VALUE IN THE CALCULATOR IS ZERO

   Explanation: The operator must verify if the result of the last operation done in the calculator is zero. If so, then the next instruction to be executed is found in frame number x, otherwise the next instruction is in the following one.

10. STOP

Explanation: The work has already finished.

Assume, for instance, that the task to be performed is just to add two number: 20 and 30, and typewrite the result. Thus, the input box has two cards. The first card contains the value 20 and the second 30. The frames have the following informations :

FRAME NUMBER	INSTRUCTION IN THE CARD IN THE FRAME
1	READ TO FRAME 7
2	READ TO FRAME 8
3	ADD FRAME 7 TO FRAME 8
4	STORE INTO FRAME 9
5	WRITE FROM FRAME 9
6	STOP
7	EMPTY
8	EMPTY
9	EMPTY

As he has learned, the operator picks up the card in frame 1 and executes the instruction of taking a card from the input box and moving it to frame number 7. Therefore, after the execution of this instruction the input box has only one card and the frame number 7 contains the value 20. The next instruction is in frame number 2. Its execution makes the input box empty and frame 8 to contain the value 30. In sequel , the third instruction is executed. In this case the operator must use the calculator to add the value of 20 (in frame 7) to the value of 30 (in frame 8). As a result the value of 50 is showed by the calculator and the operator is ready to execute the next instruction in the following frame. The instruction in frame 4 tells the operator to copy the value that is showed by the calculator on a blank card and then put it into frame 9. So far, the frames 7, 8 and 9 have cards with the values of 20, 30 and 50 respectively.The next instruction makes the operator to take the value specified by frame 9, i.e.,the value of 50 and then typewrite it. finally, the instruction number 6 tells the operator to stop.

As you can see, our operator is not a smart person. At least, he doesn't need to be because his task is just a set of mechanic operations that have to be carried out in a predefined way. Besides that, the operations are very simple. The model presented happens to be a description of a computer system where the names of the devices have been changed. For instance, the frame set corresponding to the so-called memory , the operator to the central processing unit and so forth. In section III there will be a description of the components of a computer and its correspondence to our model will be shown in detail.

The above model can be seen as a simplified computer. As a matter of fact, the modern computers' instructions are rarely much more complicated than our model(Tanenbaum , Computer, p. 1).

In conclusion, the advantage of using computers to solve problems is much more related to their rapidity and reliability in producing results than their capacity of executing complex instructions.

II - Data Representation

Human begins use the decimal system to represent numbers whereas the binary system is common among computers.

In the decimal system ten symbols namely o,1,2,3,4,5,6,7, 8 and 9, are used to represent numbers. In addition, the decimal system is said to use the base 10, which means that each digit is ten times the value it would have had if it have been placed one position to its right. For example, in 3343, the first 3 has the value of 3000 whereas the second 300 and the last one 3. Therefore, 3343 is the same as 3x1000+3x100+ 4x10+3x1. In the binary system, the above property is still valid but in this case only two symbols are used to represent numbers, i.e., the 0 and the 1[5]. Besides, the base is 2, what means that each digit is two times the value it would have had if it have been placed one position to its right. So, the value 1101 is the same as 1x8+1x4+0x2+1x1=13. Note that the first 1 has the value of 8 and the last the value of 1. Therefore, 1101 in the binary system represents the same value of 13 in the decimal systems.

The greast advantage of the binary system is that only two symbols are necessary to represent numbers. As a consequence, it is easier to represent them inside a computer because one can adopt the convention that the presence of electric current in a point of the circuit means the digit 1 and the lack of current means 0, (Mano, Architecture, p. 2). On the other hand, if decimal system is used, ten different values of electric current are needed to represent the symbols of the system and this involves serious technical problems in the design of electronic circuits.

In summary, data are represented inside the electronic computers by using the binary system because this makes

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5. Wegner, P., Programming Language, Information Structure and Machine Organization, p. 22.

easier its design.

III - Components of a Computer

Basically, computers comprise four important units, namely Central Processing Unit, Memory Unit, Input Unit and Output Unit (Wegner , Programming, p.7). Each of these components has specific functions inside the computer system and all of them are built using complex electronic circuits. Although the electronic circuits are complicated, the functions of them are quite simple. The basic entity that is manipulated by a computer is information, which can be either instruction or data(Wegner, Programming, p.3). Therefore , there must be connections between units, whereby the information can go though in order to stablish communication between these units. The following picture shows how the units are interconnected.

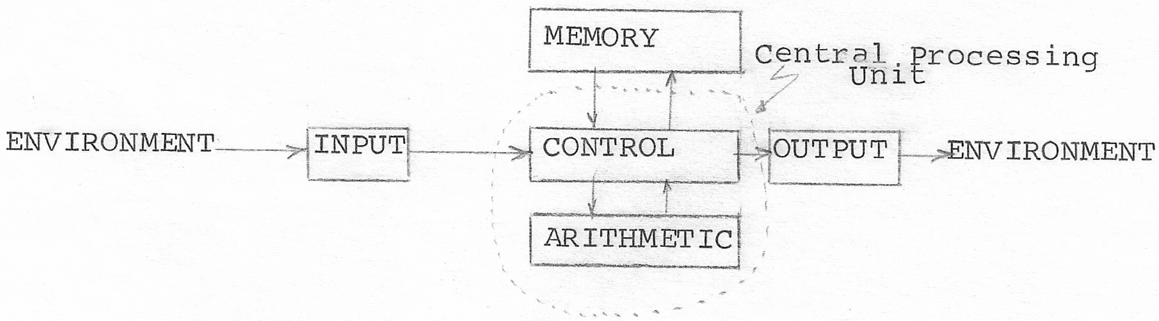

Fig. 3-1 . Interconnections between units.

Recalling the model presented in the section I, the memory unit corresponds to the frame set and, somehow, is used to store information. The input and the output units correspond to the input box and the typewriter respectively. The Central Processing Unit (CPU) is divided in two others units: the Control Unit, that is equivalent to the operator, and the Arithmetic Unit, that is the calculator.

In the same way the operator works, the Control

Unit has the responsibility of picking up and interpreting instructions stored in Memory. Depending on the type of instruction in analysis, information can be transferred from the Input Unit to Memory or from Memory to the Output Unit or then an arithmetic operation can be performed by using the Arithmetic Unit (Tanenbaum, Computer, p.19). In case of arithmetic operations, the Control Unit also must keep the result of such operations because this unit can be requested by other instruction to move this result to memory afterwards.

The most common device used as Input Unit is the Card Reader (Mano, Architecture, p.400). Usually, a computer receives information from human beings via punch cards. When the Control Unit needs an information from the environment, it requests the service of the Card Reader, which reads a card and moves its content by interpreting its holes to the Control Unit. The Control Unit, accordingly to the instruction in execution , stores the information received into memory. The cards are usually divided in 80 columns and each column is used to store one symbol. Generally, an information has more than one symbol so that more than one column can be used. For instance, the value of 123 needs three columns to be written on a card. The symbols that are accepted by the Card Reader are the English alphabet, the decimal digits and some special symbols like *,/,+ and so on. For each of these symbols there is a different combination of holes in the card. This is necessary because only the holes are read by the computer. The following picture shows the combination of holes for some common symbols. Note that are twelve positions per column in which a hole can be done.

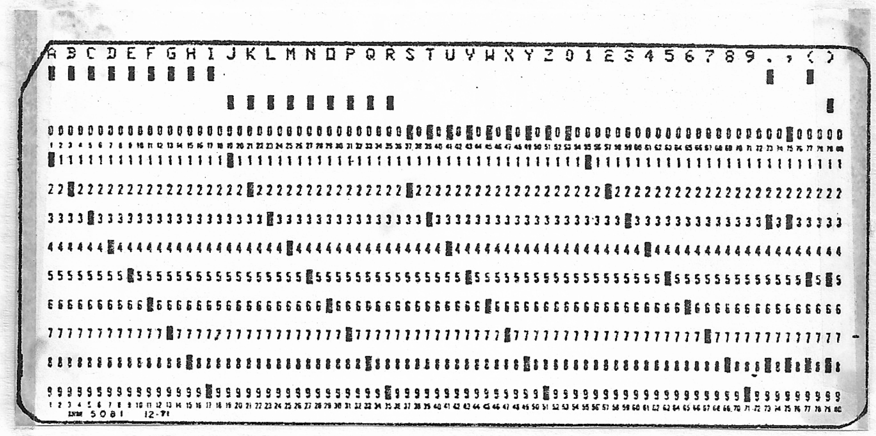

Fig. 3-2. A Computer Card

A typical Output Unit is the Line Printer (Mano , Architecture p.400), which is a device able to write about 1200 lines (132 characters per line) per minute. The function of the Line Printer is to inform the results of the execution of the program stored in memory to human beings in a readable form.

The Memory Unit that is used to store instructions and data, is divided in words. Each word corresponds to a frame in the frame set. In the same way the frames have labels for identification purpose, the words in memory have addresses. Like a frame, a word must have enough "space" to store an instruction or a numeric value. A word is formed by bits (binary digits) (Tanenbaum, Computer, p.57) . Each bit is a electronic circuit able to represent either the value of 1 or the value of 0 . The number of bits in a word depends on the computer. Generally , different computers have different word lengths. For example, the number 1101 in the binary system is represented in a memory with words of 8 bits as 0 0 0 0 1 1 0 1 . The computer is able to understand that this string of 0's and 1's represents the value of 13 in the decimal system.

In conclusion, there is a strict correspondence between the way the operator of the section I executes his task and the functioning of a eletronic computer.

IV - Instructions

Like data, instructions also have to be represented in the memory of the computer. Therefore, each instruction has to correspond to a number in the binary system because numbers are the only information representable inside a computer. In the memory there are no differences between data and instructions.When the Control Unit fetchs an instruction from memory , it receives a number as a result which is interpreted as an instruction. On the other hand, when datum is fetched, the Control Unit receives a number as a result which is interpreted as a numeric value (Intel , p.1-3).

In order to make the interpretation of instructions easier, the words of memory are said to be divided into fields. One field is used to specify the operation code of the instruction and the other the operands (Tanenbaum, p.70). For instance, the instruction ADD FRAME 7 TO FRAME 3 (section I) could be represented as | 0011 | 0111 | 0011 | in a word of 12 bits. The first field 0011 represents the operation code of ADD ,the second is the address in memory of the first operand,i.e., the value of 7 in the binary system and the last one refers to the second operand. For each instruction is defined a different string of 0's and 1's to specify its operation code. For example, 0000 means READ, 0001 means WRITE and so forth (see section I). When the Control Unit receives the string 0000 as a first field of the instruction , it is able to understand that this number is the code of the READ opera -

tion and that the second field specifies the address of memory where the information is to be read into.

This set of instructions that is accepted by a computer is said to be its machine language (Tanenbaum, Computer, p.1). Each computer has a different machine language. May be in the future all the computers will have the same machine language so that a program can be easily moved from a machine to another.

V - Conclusion

The very first computers, back in the 1940s, did not have the philosophy of putting the program in memory together with data. The programs were part of the circuits of the machine and hard to be modified or to be done (Tanenbaum, Computer, p.7). Due to the technological resources available at that time (vacuum tube) the machines were very big and slow. These computers were called "first generation" computers. Later, still in the 1940s, John Von Neumann invented the process of putting programs inside the memory, so that a great flexibility was obtained in the preparation of the programs and the operation of the machines became easier. During the 1950s, the transistor, a small electronic device to control electrons, was invented and its utilization in the construction of electronic computers made their design simpler. In addition, the computers became smaller and faster. Computers using transistor were called "second generation" computers. In the last decade appeared the so-called "third generation" computers whose architecture was based in Integrated Circuits, which are small building blocks that execute several digital functions (Mano, Architecture, p.xi). The advent of these Integrated Circuits made possible the building of powerful computers in small dimensions and able to execute more than 4 million operations per second. We are still in the age of the Inte - grated Circuits which are becoming more powerful day after day, that is, the number of functions that can be enclosed in small packages is increasing. As a consequence, the design of new computers is becoming easier and cheaper.

The tendency of modern computers is to be physically smaller because the components , the Integrated Circuits, are becoming more powerful. In addition, they are going to have great capacity in terms of memory space and variety of exe - cutable instructions.

BIBLIOGRAPHY

Intel Microcomputers: 8080 Microcomputer Systems, User's Manual , Santa Clara, California, Intel Corporation, 1975.

Mano, M.M., *Computer System Architecture*, Englewood Cliffs, New Jersey, Prentice-Hall Inc,,1976

Tanenbaum, A.S , *Structured Computer Organization*, Englewood Cliffs, New Jersey, Prentice-Hall Inc.,1976

Wegner,P., *Programming Language, Information Structure , and Machine Organization*, New York, MC Graw-Hill Book co., 1968.

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An excellent paper, interesting to read and very well done.