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THE HUMAN COMPUTER'S DREAMS OF THE FUTURE

by

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Whenever I see anyone reading a copy of Science Fiction, I gloat silently over the fact that I get my thrills not vicariously but through actual experience. Hardly a week passes by without "something new being added" to our electronic computers, and every improvement fills me with the same delight, amazement, and gratitude which I felt when I first had the joy of using this brainchild of electronic engineers, - two years ago. I come before you in the role of the well-satisfied user, ready and willing to give unsolicited testimony to the fact that your invention far exceeds my fondest hopes of the past.

Most present-day inventions, it seems to me, do not differ much from the way humanity has been picturing them in imagination for countless generations. The submarine and aeroplane must have been foreseen by many of our species from the time they first observed the ways of the fish and the bird. All tele-instruments are probably what men always hoped they might be; and the destructive power of our hydrogen bombs is no more terrifying than the Biblical prediction of their impact. But I doubt whether even the most fertile imagination possessed by a mathematician a short century ago could have foreseen the wondrous features of our high-speed electronic computer - with the magic appearances and disappearances of numbers in its storage registers; with the gratifying compliance of its control in dispatching our commands; with the incredible speed of execution in its arithmetic unit. Such reflections lead us to conclude that the future developments in this field will be stupendous, and I envy all the engineers present here who have the opportunity of taking an active part in them.

Since many organizations seek the help of the NBS in connection with their computing tasks, I am able to observe the directions in which these developments might lie. There are at least two such directions: on the one hand you will have to satisfy the demands for a small, inexpensive calculator which can almost duplicate the feats of the present giant machines in carrying out solutions of mathematical problems; on the other hand, there is a crying need for an ultra-modern bookkeeping engine capable of processing immense masses of data.

With regard to the first type, I have had so many inquiries as to what would be considered desirable features for such a machine, that I wish to take this opportunity to render a collective reply. It seems to me that prospective customers for such machines are misguided, if they take into consideration merely the initial cost of the machine. A 50,000 dollar machine may easily turn out to be far more expensive than a 250,000 dollar one, if the latter has established a record of reliability, speed, economy, and ease of application. Unfortunately our experience is still too limited, and the numbers of factors involved is too large, for anyone to risk unequivocal recommendations. The statements, then, which I am about to make may well have to be completely revised in the light of newer experience.

1. Internal access time. Having had the pleasure of operating machines displaying an access time of 12 microseconds per 50-bit word, I believe we may look forward to a period of inexpensive machines boasting of an internal access time not exceeding 50 times the above figure, without an appreciable decrease in the word-length.

2. Ratio of external to internal access time. It seems to me that there should be a fairly small ratio between the access time of a word in the external storage medium and that in the internal high-speed memory. Modern mathematical assignments involve more and more often the handling of large matrices; and machines which are constructed, at immense expense, to insure great internal speed will not be able to deal with such problems more advantageously than their much slower contemporaries, if care has not been taken to strike a nice balance between inner and outer speeds. The Univac with an average access time of 200 microseconds in its internal memory, and of about a millisecond per its 90-bit word in the external memory serves as an example of superb balance of speeds. However, the Census Bureau has suffered so many difficulties in the maintenance of this extraordinary input speed that it seems prudent not to try to emulate for some time this ratio of 5 to 1 in access times, but aim perhaps at a 25 to 1 ratio.

3. Counter-sequenced commands versus "next-command indication". I have done a great deal of coding for all types of control, ranging from one-address to five-address command systems. Recently I coded several identical problems using the four-address system (which indicates explicitly where the next address is to be found), as well as the three-address system (which allows a control counter to govern the sequence). I am in favor of the former. It saves much time for the coder, who is usually forced to make many revisions; it saves memory space -- about 17%, my examples revealed - when iterative cycles of high order of complexity are involved.

4. A list of desirable commands. The inexpensive computing machine of the near future should be equipped to execute the following commands: (a) addition and subtraction with overflow indication. By this I do not mean a red light or a stop, but a branching of command. In fact, such indication may be used for the indispensable (b) discrimination command, allowing the control to pursue either of two indicated paths. Of course there must be (c) commands for high- and low-order multiplication, and it would be well to have (d) division too, -- unrounded please. Then we must have at least one (e) extract command, preferably logical transfer, which I have found practically indispensable. (f) A shift command which effectively multiplies a given number by either a positive or negative power of the base seems to me very important, and I am constantly bemoaning its absence on our SEAC. (g) The input-output commands complete the set of desirable commands, unless the machine is sequenced by a control counter, in which case it must possess a command for the unconditional transfer-of-control, and one for storing the contents of its accumulator. Reasonable provision must be made for breakpoint, as well as absolute, stops.

If one can afford a touch of luxury in the construction of the control, I like to offer the following additional suggestions:

a) Discrimination of an absolute-value comparison.

b) A shift to normal position (for floating radix point operations) with the simultaneous storing of the exponent.

c) A command allowing a base counter to be set, whose contents would be added to all indicated addresses in subsequent commands.

d) On binary machines, two commands for converting one system into the other.

5. Portability. I expect that the superb advances made by the electronic engineers in miniaturizing the components, as exhibited for example by the Jacobs Instrument Company machine and that of the Hughes Aircraft Company, is bound to result in truly portable and easily serviced computing machines. I like to think of the day when one of those precious toys would be sitting on my desk, so that I would not have to go down on my knees begging for a few minutes' use of the computer. However, all small inexpensive machines should contain provisions for considerable growth, in the number of its storage registers, as well as in the number of its input and output units. A computing laboratory can thus be set up at a modest financial outlay, and if it knows how to make the best use of its equipment, it will soon save enough money to secure additional units to be grafted to the original machine.

6. Decimal versus binary system. Although I am fully cognizant of the advantages of the binary system, I am also fully aware that the decimal system is too indelibly entrenched in the records and mentality of mankind to hope for a universal acceptance of the, say, octal system in the foreseeable future. The use of the binary system poses no problems when relatively small input and output information is involved. But when I get those huge matrices, with all elements expressed in normal form, and remember how much time would be consumed by the inevitable two-way conversions, I cannot suppress my regret that the Good Lord had seen fit in His wisdom to endow us with 10 rather than 8 fingers. Or -- I wish I had free access to a good decimal machine.

This topic now brings me to a consideration of the other type of machine which so many Government agencies, insurance firms, banks, department stores, libraries, and numerous other educational and industrial organizations could put to excellent use. Such machines should be primarily concerned with rapid classification, interfiling, statistical analysis, and reasonable access to a vast accumulation of recorded information. On a previous occasion I pointed out the critical need for rapid and inexpensive sorters and collators which would process information stored on the same input-output medium which is handled by the computer. It is extremely impractical to use the high-speed electronic computer of today for sorting. I have used the machine for sorting in an important Air Force problem, and could achieve no better speed than about four times that of the ordinary electromechanical sorters. We need a far less sophisticated contraption for sorting, which knows how to do one thing only and does it speedily and economically. If we could achieve sorting at say 25 times the rate of the IBM sorter but at no greater expense, I could begin to hope that the tasks involved in keeping the record of the Social Security Administration might be handled electronically.

As regards random access, you all probably know that the RCA is now constructing a version of the discrete storage device - invented by our Jacob Rabinow - which I had occasion to describe in a previous talk. However, this machine offers but a partial solution to the problem of Social Security, for instance, which will soon struggle under a load of some 10^{12} bits of recorded information.

My past experience with the achievements of electronic engineers leads me to believe that all of these needs, as well as those still unfelt, will be met handsomely by them. In fact, I feel that the picture I am about to present is bound to materialize within the next score of years.

My crystal ball reveals Mrs. Mary Jones in the living room of her home, most of the walls doubling as screens for projected art or information. She has just dialed her visiophone. On the wall panel facing her, the full colored image of a rare orchid fades to be replaced by the figure of Mr. Brown seated at his desk. Mrs. Jones states her business: she wishes her valuable collection of orchid plants insured. Mr. Brown consults a small code book and dials a string of figures. A green light appears on his wall. He asks Mrs. Jones a few pertinent questions and types out her replies. He then pushes the start button. Mr. Brown fades from view. Instead, Mrs. Jones has now in front of her a set of figures relating to the policy in which she is interested. The premium rate and benefits are acceptable and she agrees to take out the policy. Here is Brown again. From a pocket in his wall emerges a sealed, addressed, and postage-metered envelope which drops into the mailing chute. It contains, says Brown, an application form completely filled out by the automatic computer and ready for her signature. Also enclosed are the facts which she had perused a moment before. Mr. Brown thanks her for the favor, and asks her whether she had ever been taken on a tour of their organization. No, answers Mrs. Jones, when would it be convenient to take her round. Right now if you can spare the time, Brown offers. Fine, Mary agrees. All at once a beautiful young lady emerges into view. She rattles off her explanations as she takes Mary - via the screen - from one room to the next.

First comes the laboratory, and the guide points to a desk-sized computer which automatically writes insurance policies on the basis of the information contained on the signed application forms resting in the machine feed unit. The guide explains that one of the problems which baffled the engineers of the last generation has now been solved, and the machine can automatically read and translate typed information into coded symbols, from which it computes and prints the required items on the policy. Mary is impressed with the compactness of the laboratory which resembles a beehive in its unceasing and methodical activity. She has just learned from the guide that she is actually viewing the inside of a vast subterranean chamber, thousands of miles away from the home office, where only the human staff is housed. Here in the cavern there are no human beings as a rule. Only when an alarm is sounded, by remote control, that some machine is malfunctioning does a maintenance man arrive to investigate.

The guide leaves the battery of policy-writing machines and walks toward the assembly of sorters. Her speech becomes a bit more technical. The outputs of the first set of machines, she says, serve as the input units for the first tier of the sorting machines. The outputs of the latter, in their turn serve as inputs for the next tier, until the last tier is reached, which produces a classified and sorted record of the new information being accrued to the Company. The input reels are marked with a brilliant design, which Mary can examine when the guide picks up an unused reel and brings it close to the screen. In motion the colors merge so rapidly that Mary finds it hard to

believe that those whirling reels wear the same design. Yes, the input speed of the future is some million bits per second, and almost matches the internal speed of a tenth of a microsecond access time per 20-decimal-digit word.

Mary is now asked to view the storage units and the merging machines. The guide picks up a bit of almost invisible wire, perhaps an inch in length. For Mary's benefit she uses two clamps to hold each end. She holds one clamp in her left hand, and starts rotating the other. The distance between the two clamps does not diminish, yet as the guide whirls the clamp, more and more wire is wound upon it. The physicists, chemists and engineers of the future will have found a durable elastic medium which, in its normal state is so congested that it can endure a large number of stretchings at any point in order to accommodate the insertion of new information between two bits of previously stored data. The storage units seem to breathe, as their bulk slowly expands while the mergers collate the output of the sorters with the older records. We don't allow this to go on indefinitely, the guide assures Mary. Do you see these huge boxes attached to the ceiling? They are the transcribers. Day and night without pause, they are transcribing the old information onto erased and freshly condensed storage wire of the type I just demonstrated. The job is so expensive that we can afford only enough machines to make one transcription a year. If at the end of that period we find that some old information has not been taken care of, we add another of these boxes to the collection. These machines do not merely transcribe the record; they incorporate, at the same time, the various amendations, augmentations, and suppressions, for which the need has been recorded during the year. We look forward to the day, continued the guide, when these transcribers will be small enough and cheap enough to allow a complete revision every month. The information includes not only all necessary records pertinent to our business activities, but also a huge number of coded programs for computing any problem which arises in the conduct of our affairs.

Let us switch now to the home office, where you will see one of the programers who developed these routines. Mary views a lovely sunny office. It is sound-proofed, explains the guide, and has the same wall-screens with which so many of our homes are equipped. Our actuaries, statisticians, programers, agents, - in fact, almost the entire staff- are given offices like these in which they may relax, between periods of intense mental activity, by dialing for any sample of the world's literature and art stored by our Government, in either submarine or subterranean caverns, for the edification and enjoyment of all the citizens. The Company has found that the savings effected by the use of electronic equipment were sufficient to allow them to install their human staff in luxurious surroundings, and also to raise their stock dividends, into the bargain.