SMALL-SCALE RESEARCH AND AUTOMATIC COMPUTING MACHINERY

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One of the widespread impressions about automatic computing machinery is that it is expensive, and that anybody who wants to do research and development in this field must first of all get a hundred thousand dollars from somewhere, probably the government.

This is an easy impression to get. For the first ten years that I was interested in automatic computing machinery (1939 to 1949), I believed it, and thought that with few exceptions automatic computing machinery was an expensive thing to be interested in.

But what are the facts? How much money is actually needed in order to do research and development in the field of automatic computing machinery? Is it possible to accomplish something worthwhile with far less than a hundred thousand dollars?

Actually, it is possible to do important and interesting research and development in the field of automatic computing machinery for less than a tenth of that sum. Also, in some cases, it is possible to do the research and development, and in addition make a practical working installation, for less than half that hundred thousand dollars.

What is the evidence for this thesis? Let us take a quick look at a number of projects in the field of automatic computing machinery costing far less than $100,000.

Projects with Immediate Applications

First: The project at the University of Manchester, England, resulting in the construction of the first model of their computer, that uses Williams cathode ray storage tubes. Cost: I would estimate under $20,000.

Let me say a word here about the cost figures which I shall give. They are in most cases just rough estimates of ceiling costs. For, most organizations of course keep their cost figures to themselves.

Second: The joint project of Potter Instrument Co., Kimball Co., and Sears Roebuck, resulting in the electronic stock tag reader. This is a machine which reads small punched tags for garments or other stock items and from them punches ordinary-size punch cards for the purpose of stock accounting. Cost: I would estimate under $40,000.

Third: the joint project of Ernst and Ernst, auditors, and Doubleday and Co., book publishers, resulting in electronic synchronizing of an Elliott addressing machine and a Remington Rand sorter. This machine greatly speeds up the accounting for two million members of eight book clubs. Cost: I would estimate under $40,000.

Fourth: the project of Ray Pepinsky started at Alabama Polytechnic Institute and continued at State College, Pennsylvania which resulted in an electronic analyzer for crystal structure. Cost: I would estimate the first stage at under $30,000.

Fifth: the project begun at New York University by two faculty members, Goertzel and Grieg, called the Circle Computer, which aimed to be a copy at low speed of the Institute for Advanced Studies' computer. Cost: the materials cost for the first model was probably under $3000.

Sixth: the project -- now a business -- of G.A. Philbrick Researches, Inc., in Boston, resulting in a low-cost general-purpose electronic analogue computer, able to be assembled from components. At the present time, $6000 would probably buy quite a useful assembly of components for automatic computation. I would estimate all the research and development cost at under $15,000.

Seventh: the project of Intelligent Machines Research Corporation, Arlington, Va., and David Shepard, resulting in the first prototype of a machine which "looks" at patterns and "recognizes" them. Cost of materials for the first model: I would estimate under $2000.

There are doubtless more projects like these. They are all projects belonging to small-scale research and development, and they have resulted or are resulting in very practical applications.

Projects with Applications that are Less Immediate

But if we give up the requirement of immediate practical applications, we can move down at least one order of magnitude in costs. We reach what may be called ultra-small scale research.

First of these projects to be mentioned is I think the Kalin-Burkhart Logical Truth Calculator. In 1947, I heard of a small automatic computer constructed by two Harvard undergraduates for only $150 of materials. True, it did not handle numbers. But it did handle logical truth values; it did calculate fast and automatically; and it did work. This was the Kalin-Burkhart Logical Truth Calculator.

Second: the robots and other machines of Claude Shannon, Bell Telephone Laboratories engineer. Some of his work has been entirely supported by himself; some more has been supported by Bell Laboratories. The projects include: a maze solving mouse, described in Popular Science for March; a machine for playing endings in a game of chess; other types of puzzle and game machines. I would estimate the materials cost for all of them as under $1500 -- a real bargain in exchange for the exploration of the principles of robots.

Third: the project of W.R. Ashby of Barnwood House, Gloucester, England, resulting in the machine he has called the homeostat. It is a little machine able to select between many possible circuits, in such a way as to make itself what may be called "comfortable". Cost: I would estimate under $100.

Fourth: the machine called the Nimotron, constructed by Westinghouse Electric, and exhibited for entertainment at the New York World's Fair in 1939. This was my first experience with a machine that would play a game with me, the game of Nim. Cost of materials: I would estimate under $2000.

Fifth: the little robot called the "Mechanical Turtle", constructed by W. Grey Walter of the Burden Neurological Inst., Bristol, England. This machine was also built for the purpose of studying human behavior in terms of a simpler model. Cost of materials: I would estimate under $300.

Many more projects might be mentioned, but I will bring the list to a close by mentioning the two small robots constructed by our organization. These are Simon, a small mechanical brain, cost of materials about $270, and Squee, a kind of robot squirrel, cost of materials about \$190. It seems to me that this second group of a half-dozen examples of projects show that it is possible to do interesting and important work, in the field of automatic computing machinery, on an ultra small scale.

Our Own Experience in Ultra-Small Scale Research

Now, from our own experience with ultra small scale research in the field of automatic computing machinery, what information can be drawn?

Well, how did we start?

Simon

We started with Simon, and the story of how we began and continued has some points of interest, and may be worth telling.

In September 1949, I talked with an old friend of mine, W.A. Porter, then finishing up his work in the Harvard Computation Laboratory, and told him I wanted to build a baby automatic computing machine for practically no money. He was keenly interested, promised to help, and we decided to start. In other words, at this point we had already consulted our five levels of policy-making executives, had come to a decision, and had saved six months of thoughtful deliberation, committee meetings, and efforts to convince people.

In a few weeks we got started, working a little in spare time, either in Medford near Boston where he lived or in Newtonville where I lived. In other words, our plant facilities were either his living room or my basement; so our expense for plant was nil, and the cost of labor was being contributed by partners in the enterprise. Porter was builder, and I was designer.

The first major purchase of materials for our machine occurred in October. Among war surplus stock on Canal St. in New York, I bought all the relays for our machine in one gulp. They cost us a great deal of money; the 150 of them cost all of \$60.

Work proceeded smoothly for about four months, and then as with every computer project, came along a crisis. Porter moved forty miles away to Brockton, Mass., yet the machine was only three-quarters finished. So, in March, 1950, I took it to New York, to Columbia University, to a laboratory course in the Electrical Engineering Dept., where the finishing of the machine became the project of two fine students, Robert A. Jensen and Andrew Vall.

Jensen and Vall straightened out some electrical engineering aspects of the machine, which I had never understood. They finished the machine, put it through its tests, and it ran successfully in May. The total cost of materials was \$270; and the total cost of labor, which had been paid for here and there to get the wiring done, was another \$270.

We decided to hold a press conference, the same as all big computer projects do, and Columbia University willingly helped. And to my astonishment, a picture of our machine appeared on the first page of one of the New York papers, and several stories came out in other newspapers. Simon had been born.

Now every computer grows, and Simon is no exception. Simon originally could only handle numbers up to 3, but now handles numbers up to 255. He started with four mathematical and logical operations, and now he can perform nine. He can grow further: for example, if we could attach more memory to him, he could really do useful work.

However, only a few computers travel. Simon is probably the most travelled of all. Simon has been exhibited in New York, Seattle, Philadelphia, Boston, Washington, Detroit, Minneapolis, three or four smaller places, and now in Pittsburgh.

Simon has led to a number of results. On some of his travels he has earned substantial income. He has helped make the principles of automatic computers clear to a number of different audiences. He has been used for instruction in a course "Digital Computers and Techniques" given in City College of New York last fall. And he has led to the construction of other robots, Squee, which has been finished, a third one we call Franken which is under way, and plans for others. And I would estimate that the out-of-pocket cost for the whole Simon project has been less than the cost of sending two men from California to Pittsburgh to attend this meeting. It is ultra small research.

Procedure

What are the procedures we have followed in our ultra small scale research?

First, as to selection of projects: We have chosen only those that were interesting, dramatic, and could be accomplished on an ultra small scale. We have not tried to bite off more than we can chew. At the present time, we have a list of fifteen or twenty projects of a type suitable for ultra small scale research, that we would like to tackle.

Second, as to the purchase of materials: We have bought from the cheapest sources we could find. Ordinarily we have bought war surplus material, sometimes regular manufactured material.

Third, as to capital: The capital required to purchase materials, and pay running expenses, was for a number of months budgeted at \$40 a month. But every now and then our robots have brought in income which have further enabled a budget of this order of magnitude to be successful.

Fourth, as to labor. There have been two kinds, labor of the usual kind, from those who are not partners, and labor of an unusual kind, from those who are members or partners in what we call our robot enterprise. Labor of the usual kind, when required, has been paid for at standard rates.

As to labor of the unusual kind: Most of the men who have worked on any project have been "members of the robot enterprise". They work part-time only. They work only time that they can conveniently spare from their main occupation, usually studying. They come and go at times they choose for themselves, according to a flexible schedule aiming at an agreed-on number of hours a week. These hours are in most cases paid for currently at a token rate, and such payments are subtracted from the member's balance in his Contingent Account. If and when any project brings in substantial income, additional payments are made to all members according to a formula. In addition, in the first few months of each year, a percentage dividend is paid on the balances in the Contingent Accounts. The arrangement in fact is something like "promissory stock" instead of "promissory notes".

There is a dividend that comes to some members of the robot enterprise. It arises from their experience in work on automatic computing machinery. For example, one member of the enterprise after he was finished with his studying and working with us was hired at an annual salary that was \$1100 a year more than he would have received without his experience with us.

Reasons for Ultra Small Scale Research

There are at least five good reasons for ultra small scale research in preference to research on any larger scale.

The first reason is that you may not have \$100,000 nor even \$10,000, and perhaps not even \$1000 to spend for this purpose.

Second, in ultra small scale research the funds are expendable. It is like playing chess for the fun of it instead of seriously -- you can take risks, your moves are expendable, you can try an attack that looks exciting even if risky.

Third, because the funds are small, you are compelled to do a fair amount of original thinking, you must take a great many shortcuts, and you thereby will gain a great deal of efficiency.

Fourth, it gives you first-hand contact with automatic computing equipment in the flesh, I suppose I should say, in the hardware.

Fifth, it gives you experience and training which pay dividends to you in all the rest of the work that you do.

Awards

Now, as you may suppose, we have come to the conclusion that a great deal can be done to advance the understanding of automatic computers and related subjects through the practice of ultra small scale research. We are in favor of it, and we should like to see the practice spread. In order to help it along, we are going to give small awards from time to time to qualified people, to help them carry it out. There are no "strings" on these awards. They are not contingent on our organization acquiring any rights.

Part of the first award has gone to a student in one of our courses in Wyoming, who is working on a miniature electronic digital computer.

If you or if any one you know wants to do ultra small scale research in the field of automatic computing machinery, perhaps we can help him, and we would like to have him get in touch with us.