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AUTOMATION OF CALCULATIONS AND THE DEVELOPMENT OF COMPUTER ENGINEERING

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- USSR -

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AUTOMATION OF CALCULATIONS AND THE DEVELOPMENT OF COMPUTER ENGINEERING

- USSR -

[Following is a translation of an article by M. A. Kartsev, Candidate of Technical Sciences, in the Russian-language periodical Vestnik Akademii Nauk SSSR (Herald of the Academy of Sciences USSR), No 11, Moscow, Nov 1962, pages 64 - 69.]

Electronic digital machines are primarily utilized today for calculating strictly computational work, and only in comparatively simple cases are they employed in automatic control systems. Whatever may be said about self-teaching, self-adjusting and self-organizing systems, etc. belongs at best in the realm of pure theory.

Nevertheless, a considerable amount of what is required to produce such systems already exists within general outlines, and it is now time to undertake the first practical steps in this direction.

We surmise that it would be advisable to construct such a system for calculating as our first step. Computer engineering is an especially ideal experimental field for improving digital devices primarily due to the diversity and comparatively thorough investigation of algorithms.

The need for a strictly computational technology simultaneously demands further automation of calculation.

The fact of the matter is that a modern calculation center equipped with just a single heavy duty electronic computer generally requires a staff of 50 or even 100 people to provide its continuous use for mathematical and technical purposes. The establishment of such centers was justified in the past when machines were scarce and

and it was necessary to use any means to carry out specific calculations. Such a method is evidently inadmissible in the future, however, especially because future production of computers would divert for the application of these machines the very specialists who might engage in new research and developments in digital engineering.

This is the reason for the urgent need of further automation of calculation and progress in establishing computation centers founded on substantially new principles. It is precisely the computation center of the future -- the automated computation center -- which will be the first practical realization of a self-organizing, self-teaching and self-adjusting system.

The possible structure and organization of such a center is examined in general outline below.

It appears to us that an automatic calculation center will consist of several computers of a single series interconnected by a commutation system. It is not mandatory that all of these machines be completely identical. They may differ in operation speed, in the number of inputs, the size of the memory unit and possibly even in the number of digits, flowsheets and different parameters. When we say that the machines should belong to a single series, we understand an identity of data input methods, of the basic structure of the machine language and the parameters of input and output signals.

It is desirable that all the equipment in the calculation center be duplicated to some extent, i.e. that the operations performed by some machine or installation be performable by another installation or machine as well. The very same tasks could therefore be solved at least by different machines using divergent methods, possibly at different times and even with varying degrees of accuracy. But somehow the possibility should be provided of getting along without a certain part of the equipment.

The following problems might be solved by setting up the automatic center: maximum automation of programming, automatic distribution of problems among the machines and in time, the organization of simultaneous work within several machines when solving especially complex problems, automatic distribution of equipment among the machines (outside devices, operative memory banks, etc.), maximum automation of equipment maintenance control and automatic follow-up and recording of the work performed by the calculation center.

These functions will mainly rest within one of the machines which will become the master computer.

We will first examine the possible order of information input at the calculation center.

All problems turned over to the calculation center for processing are first fed into the master machine. Information about these problems can be recorded, for example, on a magnetic tape which is then put into the outside system of the machine. The tape will not contain information about a single regular problem, but about an entire group of problems, or let us say, about all the problems received by the center at any particular hour. Consequently, prepared problems will not be fed in according to how free the equipment is, as is now done, but rather in proportion to the inflow of problems.

Information on each problem must consist of two parts -- the material portion where the formulation of the problem is transcribed, and the operational portion containing an ordinal number, information on the priority of the task or the importance of controlling the results, and on whether the given problem is a one-shot operation or repetition is anticipated in the future, etc.

The material part of the information on a certain problem can be programmed in a general form (in letters). Instead of this, however, either an algorithm of the problem's solution can be transcribed in operational form (which is for the most part the initial information for modern programming), or or even still shorter formulation of the problem in symbols approaching the commonly accepted mathematical symbols.

All three methods of transcription will probably be used for the real problem in its various parts.

It is assumed that automation of programming at the automatic computation center will be realized on a substantially larger scale than is currently being done with routine programming.

Work on automatic programming being done at the present time has been encountering two large-scale difficulties. First, programming has to be set up so that a particular computer schedules its own program in accordance with it. It would be more convenient however to program for any machine by means of another larger machine. The second difficulty is associated with the fact that the distribution of machine types today does not lend itself to automatic programming. These were constructed with manual programming in mind.

Both difficulties may be surmounted by establishing the automatic computation center. Provided the master computer which is basically used for programming does not differ in type from the other machines present, it can take in a part of the hardware of the other machines (operational memory units, magnetic tape, etc.) or even feed these machines on the whole certain bits to make up the program.

A brief formulation of a certain part of the problem given in symbols can be used if algorithms of the solution have already been worked out for this part of the problem. These algorithms in nearly complete form should be introduced earlier into one of the outside memory units of the master machine where they are constantly kept in operational form (the storage unit of standard algorithms). In some instances the hold unit can store certain algorithmic variants, e.g. to solve systems of algebraic equations, systems of ordinary differential equations, etc. Each variant should then be accompanied by additional information on its limits of applicability, on the dependencies which are as it were necessary for realizing a number of memory nests and operations from the series of the system of equations or perhaps from the relation of the coefficients, etc.

Once the information is received on a particular part of the problem in brief mathematical form, the master should first select the appropriate algorithms from its storage unit and evaluate the amount of equipment and time required to carry them out. Information on certain possible variants in the selection of algorithms may then perhaps manage to be stored for some time in the operative memory of the master machine. In selecting the algorithms later on, concrete information will have to be introduced, such as on the order of the system of equations, the number of interaction cycles, etc. The point of this work lies in its being performed after final selection of a single specific algorithm.

Consequently, the case of initial information entering as brief mathematical formulation will in the final analysis be reduced to its being immediately received as a finished algorithm. The initial information must be processed directly in this form for parts of the program lacking stored algorithms. The initial information can be transmitted in this form if it is supposed that standard algorithms are not suitable for the given concrete case.

Finally, it makes sense to introduce the input information as a complete program (in letters) whenever the human operator preparing the problem thinks that it will be simpler for him to set up the program of any part of the operation with complex logic than to explain to the machine how to do it. The machine will equally convert from operative transcription of the algorithms to this form of recording information, using stored standard subprograms and scheduled programs in the modern sense. But once again several variations become possible (e.g. upon selecting standard subprograms from storage).

Before finally specifying the algorithms, making final selection of the standard subprograms, converting from letter coding of the program into numerical code and feeding the finished program to the other machine which will implement it, the master computer will still have to perform an important part of the operation. This consists in an overall evaluation of the complexity of the problem for the various possible variations in its solution, in comparing them with the operational part of the information on a given task and with analogical data on different tasks, as well as with information on the condition of the equipment in the computation center (its load, performance, etc.). This will yield the final data which we will discuss somewhat later. Based on these comparisons using a number of criteria it is decided when, on what machines and in what condition of the equipment the problems at hand are to be solved, as well as which of the possible variations in the assortment of algorithms and standard subprograms shall be adopted for each of the problems and how the control for each operation will be organized. Such a solution should on the one hand provide a fair sequence of priority (considering time of receipt and priority of the assignment) and on the other, the highest productivity of the computation center. The latter implies that at the outset of the solution of any problem it is necessary to complete the programming for it, to free all required equipment, prepare the commutation circuits, etc. The idle time of the particular devices should be minimal during this period, and the algorithms selected to solve the problems should correspond in the best manner with the equipment personnel.

Situations may arise where the optimum algorithms for some problem or other differ under various conditions. For example, if problems come in at the same time as the solution of a given problem on other machines where a large-size memory is not required, algorithms can be chosen which provide top speed while needing a large amount of memory units. In other cases it is possible that there will be no point in waiting for the additional memory blocks to become free, but better to solve the problem by a more deliberate method.

The relation between the hardware in good working order and that in repair exerts a substantial influence on these decisions. It is essential to always be able to forecast the working condition of the equipment and to have spares at hand. It is best not to keep specially stored hardware in reserve (which would actually be poorly used), but instead reserve variations used in the operational sequence, methods of organizing the control of calculations, etc.

Hence, the computation center will be a complex self-adjusting system in which the selection of the operational algorithms will be determined on the basis of the conditions that are conducive to maximum productivity, considering both the external factors (existent at the time of the operation) and the internal condition of the system.

The criteria according to which the algorithms are selected may be adopted earlier, but must be further specified during the operation. Specification primarily requires numerical characteristics of different algorithms such as the time required for calculation with the given algorithm, the time the particular hardware will be in use, etc. Certain elements of self-instruction are contained in the introduction of a precise kind of specification.

It is however possible that the self-teaching process will succeed in being widely used. It is easy to imagine, for instance, that with the transition from operative transcription of algorithms to general programming the master computer will simultaneously consider how often the particular combinations of operators occur. Portions of the program corresponding to the most frequently encountered combinations can then be put into the standard subprogram storage.

By proposing several alternates each time for any operator or combination of operators which may be substituted by standard storage subprograms, it might be possible to analyze at the same time those situations in which each of the alternate variations is at its best. The data may be later utilized for immediate selection of the optimum variation.

A similar self-teaching process can also be provided during the stage where initial information is converted from the transcription made as a brief mathematical formulation to the operational writing of the algorithm.

The self-instruction program could possibly be amplified. New divisions could be added after the previous divisions have been adapted and reinforced, i.e. when the master machine has sufficient time reserves to undertake further self-instruction.

It is important to note that the computation center will not only be self-adjusting and self-teaching but a self-organizing system as well. This is due to its optimum algorithms not only varying in relation to external circumstances and intrinsic condition of the system, but its internal structure structure also being modified, i.e. the particular hardware belonging to definite machines, the commutation circuits, etc.

One should particularly dwell on how the control of equipment functioning, its cleaning and repairs can be accomplished when the automatic computation center is established.

In modern computation machines the basic methods of operational control are the autonomous apparatus controls of the individual devices (for instance, parity control for memory devices, modulo 3 or 7 control for arithmetic devices, etc.). and double checking the operations made according to a single program although at different times.

At the automatic computation center a reciprocal control of the machines should take the place of the double check. This method is, in the first place, more reliable than the double check, since the probability of singular errors arising on two different machines is obviously considerably lower than the probability of the repetition of the very same error during the completion of identical operations on a single machine. In the second place, it is favored by the controlling machine being able in principle to be included in the operation and excluded from it at any stage in the computation. If the controlling machine is on all the time, the deviation signal can be received immediately following the deviation and not after receiving the final results (as occurs with the double check). Finally, the different results obtained by the double check merely indicates the occurrence of errors, without in general making it possible to determine which of the two results is the correct one. Test runs could be made on both machines used in reciprocal control right after the divergent results are received. The machine correctly solving the test problem most probably yielded the true result in the initial operation. A third machine could be brought in as an umpire as another alternative.

Test programs should be squeezed into the intervals between calculation of the basic problems not only when malfunctions arise, but also with circuit checks after specific intervals of time. Automatic checking will be particularly effective if a programmed change in the feed voltage is provided to the individual devices, as well as possible automatic measurement of the feed voltages and their rated input to the operational memory of the master machine through the voltage to digit converter. Together with this programmed variations in the cadence frequency, simulated outside interference, etc. are possible. Applying the reciprocal control method makes it possible to accurately pinpoint under what conditions and in which operations the particular device falls out of alignment. It is possible that special control programming can permit the place where a break-down arises (unit, block, etc.) to be located with more or less accuracy.

On the basis of the checking procedures and data on failures in the operating condition the master machine can decide on sending the particular devices out for repair. Upon having made this decision, the master stops loading the equipment needing repair with any operations, and sends out information through its output about which device and why it has been put to repair. Such information should contain the most ample description possible about the faults that were detected.

Error control in the master computer itself is constructed on the same principles. When deviations are discovered even in the most difficult combinations of deviations in feed voltage, the master machine should either shift a part of its devices to others or switch its functions over to another machine. After some time it may once again be used as a regular machine. But the role of master is too responsible for it.

Besides information on equipment put into repair, the output installation of the master computer should also continuously supply information on the problems being calculated at a given time, when the solution of other outstanding operations is supposed to begin, and on the condition of the equipment at the calculation center (e.g. at what limits in the variation of feed voltage the efficiency of individual devices is maintained, etc.). It is possible in certain cases that the master computer will be required to report the methods of solution which have been chosen for specific operations (algorithms, subprograms), how the control has been set up, etc.

The establishment of an automatic calculation center is a large and complex task. Problems both large and small will have to be solved and many serious difficulties overcome. The solution of such a problem demands the long-term, intensive and purposeful labor of a large group of engineers, programmers, mathematicians and workers in different specializations. However, there are no obstacles in principle to the solution of this problem. Its practical and theoretical significance is unquestioned.

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