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REAL-TIME, TIME-SHARED COMPUTER PROJECT

Fourth Quarterly Progress Report

October 31, 1961

XEROX

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Summary

Over the past quarter, firm decisions pertaining to the hardware makeup of the time-shared 7090 system have been made. Based upon these decisions, three remote consoles, complete with a digital plotter (for graphical output), type-writer, and a graphical hand-drawn input device are being constructed. To control the plotters, a special-purpose computer is being built. Of these three units, only the hand-drawn input device is still in prototype design and construction stage.

Having made these hardware decisions and a decision to use an existing algebraic language and compiler (MAD) for on-line symbolic input, work can now go rapidly ahead upon modifying this compiler to provide increased time-shared computability and efficiency, including plotted outputs and hand-drawn inputs for IQ.

The major decisions with respect to scheduling and memory allocation have now been made and will be incorporated in the operating system.

The major emphasis of the project is now relatively free to move over more heavily into the end usage and software problems of man-machine interaction.

I. Study Areas

a. Graphical Languages

Now that almost all hardware aspects of the system are reasonably well specified, attention is being very strongly directed towards end usages, and in particular, the classes of computation requirements that should be met, as well as the best language forms for specifying and perceiving results.

To this end, members of the group are now working closely with research groups in network theory, plasma research, materials research, and solid state physics. In addition, a number of theses for specific types of problems are being undertaken to arrive at better languages with primary emphasis upon input languages.

The graphical languages being considered now include hand-drawn, two-dimensional mathematical formulas, flow diagrams, network diagrams, and dimensioned drawings. The most general requirement for output languages would seem to be in the direction of providing versatile plots of functions.

One of the most common of the desired capabilities is that of solving and simplifying involved partial and ordinary differential equations to obtain reasonable approximations.

Much more work needs to be done in this area and increasing emphasis will be given to it as other parts become operational.

b. Memory Allocation and Scheduling

A relatively straightforward algorithm has been developed for the decision procedures involved in scheduling within the time-sharing system being developed.

As has been previously reported, the basic scheme for time sharing will involve running programs sequentially (but not necessarily to completion) for short periods of time, after which the programs are sent out (via channels) to temporary (disc) storage until their turn in the "ring" of running programs came up again. This scheme requires a minimum of memory space for three programs: One of which is running, the second on the way in or out, and the third small program controlling the I/O messages and scheduling.

The basic criteria of this scheme has been to maximize efficiently (defined here as the percentage of total machine time devoted to useful computation), subject to a constraint of not inducing noticeable delays at consoles. A tentative

goal for efficiency of about 95 per cent has led to a running time cycle of about 2 seconds on the 7090.

Until recently, one unsolved problem has been the question of determining the order in which programs should fit into the "ring" of active running programs.

A relatively simple (and computationally fast) algorithm for determining the order has been developed. The procedure involves sorting the active programs in order of memory size, then interspersing the small-sized programs in increasing order in between the large-sized programs in decreasing order. Based upon the distribution of program sizes (excluding compilers) that has been determined in the past, this procedure should produce the desired results.

c. Information Retrieval

The question of long term storage needs for data and programs (source, intermediate, and object language) is now undergoing some scrutiny. In particular, the questions of specifying what is to be retrieved, what is to be kept, and for how long and in what form the data are to be kept are of importance. No striking solutions have yet presented themselves, but the problem is capable of being solved by simple successive "cut and try" procedures

II. Hardware

a. General

The project has now largely determined the makeup of the input-output consoles, and with this decision, software, as well as hardware plans, are becoming firmer. The capability of each of the three presently-planned stations will include graphical input-output with hard copy byproducts, as well as flexo-writers (punched tape, keyboard, and typed I/O).

It is now felt that this set, while perhaps lower in data rate than ultimately desirable and relatively unintegrated, (the graphical output should ultimately be combined with graphical input and used for symbolic output as well, retaining only the keyboard of a typewriter) will be highly adequate for the language, system and programming development. In addition, work to improve these capabilities is continuing.

b. Output, Graphical

A basic decision with respect to output has been made in settling on a particular, low-cost, commercially available digital plotter, the Calcomp 560R, for graphical output at the remote consoles. This device, which has a .01" resolution, and a 4"/sec. (max) plotting rate, would seem quite adequate for almost all plotting requirements considered and has the added virtue of providing hard copy. Its plotting rate, while low, is felt to be in keeping with the overall philosophy of the time-shared system, i.e. to keep the input-output rate consistent with a small fraction of the computer's capacity. Although research is continuing on higher data rate, hard copy devices for graphical output, it is no longer a matter of urgency, and the exploratory work on cathode ray tube graphical output and its associated data storage for display maintenance has been slowed down. The much greater cost and extreme data rate capability of such devices are now felt to be both unneeded and unwarranted, and in any event, are now undergoing extensive development by the computer manufacturers.

The digital plotter, in its present form, responds to single increment signals in $\pm x$; $\pm y$ and "pen up, pen down", which it can accept at any rate up to 200 increment commands per second.

To provide buffering between these units and the 7090 computer, as well as to change the output format into straight line segment form (delta x, delta y, slope), a special-purpose computer has been designed around a Bernoulli disc magnetic storage. This computer, which is now being built, will have the capability of storing up to 64 line segments for each of twelve independent satellite plotters, converting this information to the form needed by the plotters at their maximum plotting rate, and accepting bursts of new data as the old is exhausted. The plotter can, of course, be used in place of a typewriter for symbolic output as well, but except for very small characters, the rate of plotting is somewhat slower.

The computer and three associated plotters are expected to be on-line early in 1962. In the meantime, for experimental purposes, a single plotter has been directly connected to the IBM 709 computer.

c. Input-Output, Typewriters

An additional flexewriter has been obtained and is being connected via previously-designed converters to the present input-output buffer unit.

d. Graphical, Hand-Drawn Input

A prototype unit for hand-drawn input has been designed and portions tested. This low cost device, when completed, will be capable of .01-.02" resolution (less than pencil width), an input data rate greater than 1000 points per second; with two modes of input to a computer: either line segment (ordinates, slope and length) or point coordinate (10-bit binary x and y),

Unlike a light pen, the device will work with ordinary paper and a modified pencil and will not require the use of the computer in order to operate.

Consideration is now being given to the design of a suitable, low cost, special-purpose computer for decoding handwriting and buffering many such simultaneously-used devices to the single computer.

III. Software

Programming work is continuing in areas relating to input, output, modification of compilers, and scheduling. The work is progressing well, and is being coordinated with the planned devices for the 7090 computer.

a. Output, Graphical

General routines are being written to provide for graphical output in the form of linear, semi-log, and log-log plots for one-dimensional results, as well as contour maps for two-dimensional quantities, utilizing the digital plotter. Coordinate, point, and textual labelling facilities are also being included in these routines, utilizing a specially-designed character font. This font will include English, Greek and most of the mathematical symbols, as well as super and subscripts.

When complete, these object language routines will be capable of being compiled into algebraic-language object programs, utilizing an appropriate set of plotting statements.

It is relatively certain that we are, as of yet, still scratching the surface with respect to the range of desirable forms of graphical output, not to mention reasonable sets of transformations of output.

b. Scheduling, Memory Allocation and Input-Output Control

Outside of small-scale simulations, the final programming of these functions has not yet begun. The analysis of how they are to be done, however, is relatively complete.

c. Modification of Existing Compilers - Analysis Programming

The capability of the analysis program developed by this group to aid in rapidly rewriting and reorganizing existing compilers has been expanded, primarily for purposes of reducing the volume of analyzed program output, as well as for the purpose of producing flow charts of analyzed programs on the digital plotters. The flow charting capability is not yet complete.

d. Modification of the "MAD" Compiler

A basic decision has been made to use the "MAD" (Michigan Algorithmic Decoder) source language for the primary "keyboard input" symbolic language of this system.

The major programming changes to be achieved upon this compiler are the following measures, aimed at reducing memory requirements, increasing capability, or decreasing the running time of object programs.

1. The program is to be broken down into nonoverlapping phases, only one of which will be in memory at any given time.
2. The textual form of all diagnostic messages will be put on accessible, but not internal memory.
3. All tables and data resulting from each statement will be put out in blocks on tape, rather than occupying memory (until actually required).
4. Insertions and deletions of statements will be possible without a complete recompilation.
5. The present handling of arrayed variables will be modified for reasons of both speed and minimization of errors.
6. Plotting routines will be included in the source language.

e. Handwriting Input

Extremely fast routines are now being programmed and tested for the use of on-line handwritten (disconnected) characters. The character font to be recognized, and the specific routines for decoding will be specific for each separate user. The user will supply once a complete sample of the characters which he will use, and the routines, based upon their analysis, will generate a small program for the analysis. The routines are being designed to have a high rejection rate in the case of uncertainty so that errors can be immediately corrected.