On the horizon: better hospital care through computer time-sharing

When the Hospital Computer Project becomes operational, it will free the medical staff at Massachusetts General Hospital for better patient care based on real-time research information.

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For the past three years, an active research program has been under way to develop a time-shared computer system that may revolutionize techniques of patient care and hospital administration. The new system, known as the Hospital Computer Project, is the prototype for a group of regional computer systems that will do the routine data processing, record handling and statistical research that now takes up much of the time of doctors, nurses and other highly skilled personnel. Not only will such a system free these people for the more urgent tasks connected with patient care, but it will also provide an invaluable adjunct to diagnosis, treatment and research.

The medical profession and the scientific community have applied new computers and new techniques of information technology to the statistical analysis of clinical observations, the gathering and processing of data directly from patients, and the quantitative study of physiological systems and conditions. However, despite spectacular progress in these areas, there has been little application of on-line computers to the solution of problems surrounding the generation and use of the patients' records, or to medical research based on the accumulation of such data.

The broad goal of the Hospital Computer Project, a joint effort of Bolt Beranek and Newman Inc., and Massachusetts General Hospital, is to apply a time-shared computer with remote input-output devices to the rapid and accurate collecting, recording, transmitting, retrieving and summarizing of information about patients; to reduce the nurses' paper work; to arrange and consolidate information for the medical staff; and to develop a system that will store large amounts of complex medical information and also rapidly retrieve it for clinical research.

Another major goal is the design of a flexible system that can be used by a number of hospitals. Large metropolitan hospitals might afford to own their own computers, but smaller institutions could not. And more than 50% of the nation's total hospital beds are in hospitals with fewer than 200 beds each. Time-sharing a computer could reduce the cost to each hospital to an acceptable minimum, and would permit an interchange of information that should improve patient care.

If the goals of this project are to be achieved the medical staff must accept a time-shared computer system, with all of its psychological and sociological implications; it must understand the computer, and be able to communicate with it.

Because data on the care of patients and clinical research information will be fed to the computer, eventually it should be possible for a doctor to get real-time research results—that is, soon enough to aid in diagnosing and caring for a patient. He can

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CALL     MEDA


   MEDICATION ORDER



9:56 AM 3/1Ø/1965
1  TIME AND DATE
2  DOCTOR  BROWN,R
3  PATIENT  4Ø8B  DOE,JOHN  MR 1234567  M
4  ORDER
  4.1   RX,ACHROMYCIN,5ØØMG,PO,Q3H,I
   TETRACYCLINE HCL
 MAXIMUM SINGLE DOSE EXCEEDED
DOSE ?  1ØØMG
RX,TETRACYCLINE HCL,1ØØMG,PO,Q3H,I
  4.2    RX,DIGITALIS,Ø.2GM,PO,1ØAM,I
 MAXIMUM SINGLE DOSE EXCEEDED
DOSE ?  *Ø.2GM
RX,DIGITALIS,*Ø.2GM,PO,1ØAM,I
  4.3
5  INITIALS  CD

-THANK YOU-
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Typical conversation between a doctor and the computer.

1. The computer prints out the time and date.
2. The computer asks the doctor's name, and the doctor identifies himself.
3. The doctor identifies the patient by number; the computer corroborates this by typing the patient's name and other data.
4. The computer requests the medication that the doctor is prescribing. As the doctor specifies each item, the computer questions any errors.

4.1 Tetracycline HCL is the generic name for the drug that the doctor specified by its trade name; the computer questions the 500 milligram dose and allows the doctor to change it.

4.2 The computer also questions the 0.2 gram dose of digitalis, but the doctor confirms this with the asterisk.

4.3 The computer confirms each entry by typing back the corrected order in full.

5. The doctor signs off with this code and the conversation is finished.

ask, for instance, "What happened to the last 25 patients who had pneumonia and ulcers at the same time? Was drug X prescribed for any of them? If so, did it help them in any way?" Questions like these now require weeks of research and cannot be answered in time to help individual patients.

Interpretive communications

The system under development at Massachusetts General Hospital is called an interpretive communication system. The content of each message is analyzed by the computer and compared with previous messages. If the message contains information to be stored, the computer sorts out the data and stores each segment in the appropriate part of its bulk memory; if the message requests information, the computer retrieves the data and transmits it to the person requesting it.

Different kinds of messages might ask questions about patient care, request laboratory reports, set up admission of new patients, and so on. The computer knows which kind of messages are likely to come from each terminal, and processes them or rejects them. For example, a doctor may use a terminal in his office to order medication for a patient. The computer asks for, then checks the doctor's name, the name of the drugs prescribed, permissible dosages, and so on. A sample print-out is shown in the diagram at the left.

If a terminal in the admissions office is used to transmit an order for a medication, the computer would reject the request, because the clerks in the admissions office are not authorized to order medication. On the other hand, if a laboratory terminal is used to enter information about a newly admitted patient, the system will accept the data, but with a warning that the terminal is being improperly used.

All the programs in the hospital system are used in the conversational mode. The dialogue begins when a user requests a specific program. Either the computer or the user will type a question and obtain a response. If the user is in doubt, he will ask the computer how to reply by typing the word "how?" and the computer will give instructions.

An unusual feature of the system is that it can work with either of two versions of the conversational-mode language, either long or short. For instance, two versions of the same request by the computer would be "Patient identification" and "Pt." A user familiar with the routine might prefer the short version.

In addition to routing messages, the system will organize messages, file them, and make them available on authorized request. Messages containing results, as opposed to messages asking questions, are automatically routed to the proper storage location where they contribute to the accumulation of statistics—for instance, on the treatment of patients with both pneumonia and ulcers.

If information entered is pertinent to other terminals, the computer will route it whether the user requests it or not. A grossly abnormal test result or a questionable drug order, for example, will be routed out of its normal sequence and sent to appropriate terminals.

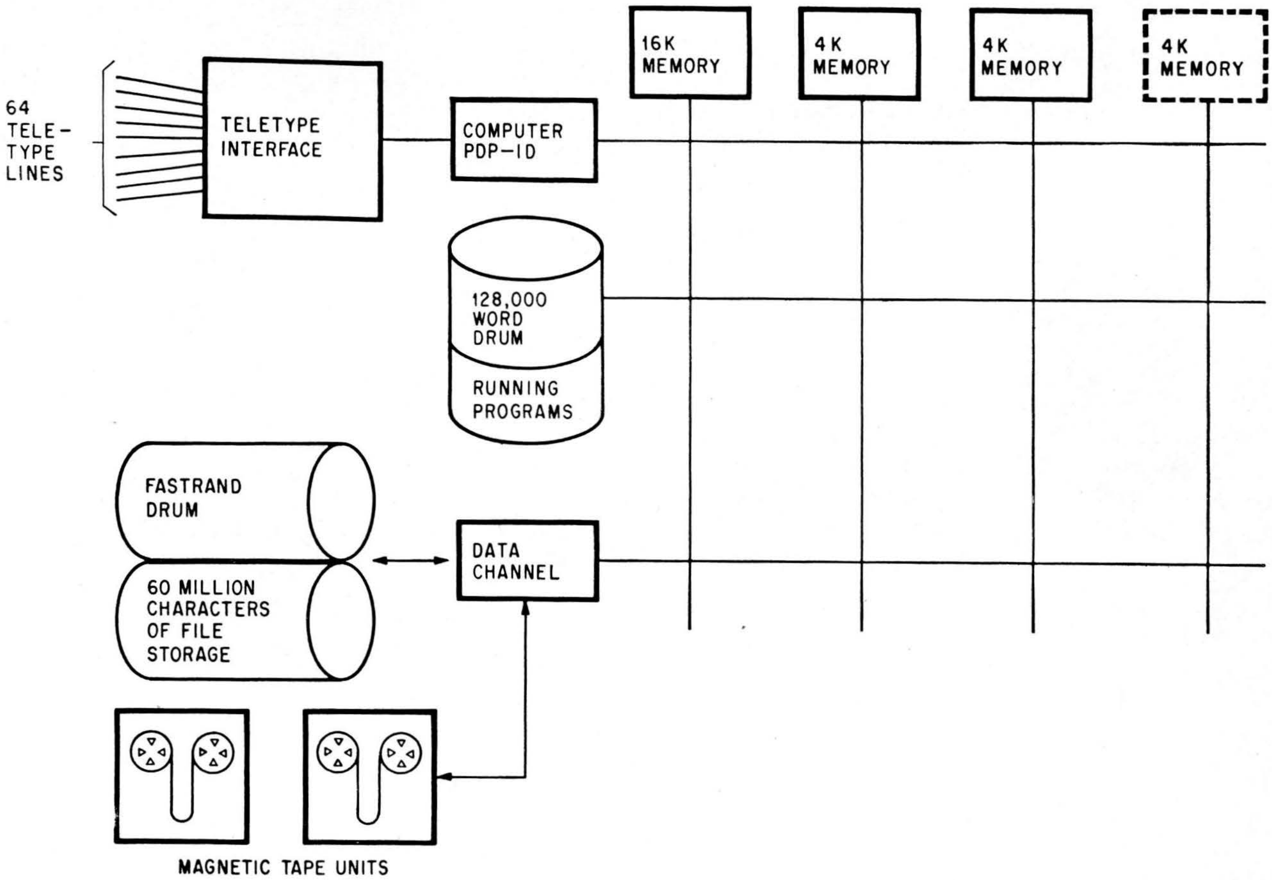
The file structure is organized to store large quantities of medical information that can be used from day to day even though the information is constantly being changed. There are also provisions for an individual researcher to create new files compatible with the over-all file structure but with a format that suits his particular investigation.

Furthermore, since the system will be performing medical rather than computational tasks, its computer will make few demands of the users and require a minimum of training. A flexible, expandable system relies heavily on a set of generalized programs that provide necessary user services.

System hardware

The computer now being used in the Massachusetts General Hospital system is shown in the

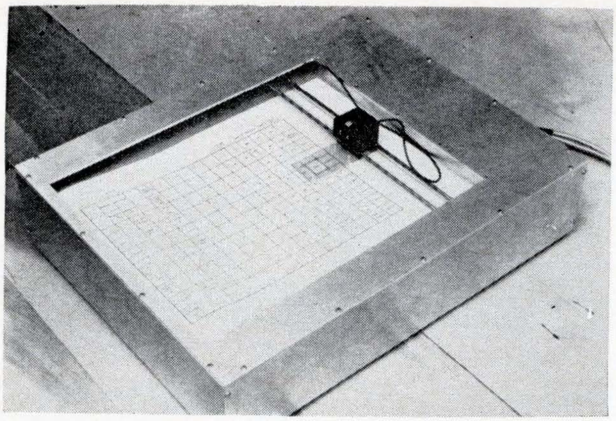
Massachusetts General Hospital's computer system for medical record-keeping and research. The computer, installed at Bolt Beranek & Newman Inc.'s laboratory in Cambridge, is about seven miles from the hospital. The computer can be seen immediately behind the operator's panel to the right of the man at the teleprinter. Behind the computer are the memory banks; in the extreme rear is one corner of the drum storage unit; tape drives are visible at the right.



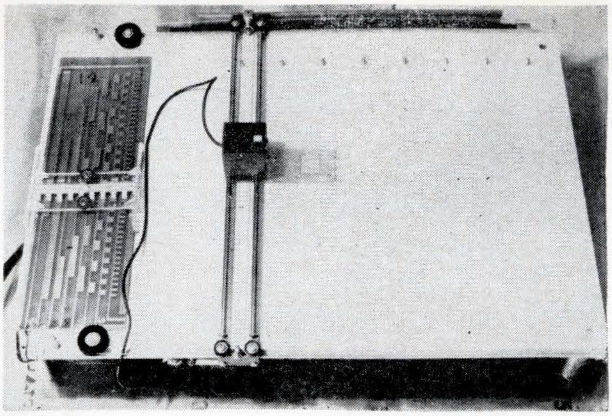
The computer system shown above is diagramed here. The dotted line indicates a 4,000-word memory that is within the capacity of the system but is not presently installed. All the 4,000-word memories can be expanded to 16,000 words. The single 16,000-word memory contains the supervisory program.

photograph above. The block diagram shows the computer's organization.

The Hospital Computer Project grew out of Simbug (for simplified debugging), a very early operating time-shared computer project developed at Bolt Beranek and Newman Inc. It used a Digital Equipment Corp. PDP-1 computer with which up to five users could debug programs simultaneously from console typewriters. The basic PDP-1 comes with 4,096 words of memory and a single-channel interrupt system—that is, it can react to only one kind of external interrupt. For Simbug, a 16-channel interrupt system was added. One kind of interrupt is a signal from the drum that a requested program has been found. Another kind signals the arrival of a character from a teletypewriter, and so



Prototype Datacoder terminal used with a teleprinter for quick and accurate input of repetitive data. Data is selected by placing the little window over the appropriate square and pressing the button on the slider. This transmits two Teletype characters that give the location of the window, thus indicating the item specified.



Datacoder terminal with the covers off. A sheet of grid paper with standard data marked in the squares is placed under the cursor. It is registered by the row of pegs at the top, which fit in holes in the paper. The printed conductor pattern at left translates the position of the cursor into an 8-bit binary code for transmission to the computer.

on. Simbug also required additional memory, logic to prevent user programs from interfering with the supervisory program or with each other, and a magnetic-drum storage unit for holding programs not in immediate execution. With the new central processor, an altered version of the PDP-1, most of the problems encountered by the prototype system built around Simbug have been solved.

A swapping drum is required in most time-shared systems with limited core capacity. The present system includes two drums: a high-speed drum for memory exchanges, and a lower-speed drum for bulk random access storage. The latter is a Fastrand built by the Univac division of Sperry Rand Corp.; it has approximately 60 million characters of available storage space, and fulfills the need for a large area in which to store medical information.

The computer can run in either of two modes—an executive mode where all commands are executed, and a user mode, where user commands that might adversely affect the system are intercepted for examination by the executive program. When this happens, the user loses control momentarily; the executive program may correct his error or advise him to try again.

Memory subdivision

An independent memory scheme divides the memory into four groups, each operating independently. Logically, memory is treated very much like a tape-drive or a card reader; the main arithmetic and control unit requests data from memory or stores data in memory. Memory control has also been given priority logic so that it will be accessible to more than one processor.

The present configuration includes one bank of 16,000 words, containing the executive program, and two 4,000-word banks for users. With the independent memory scheme, one user program may be swapped to or from the high-speed drum into one of the smaller banks while another user program is running in the second bank. Since the computer is always running and always has access at least to the executive bank, it never has to wait for the swapping drum and can handle interrogations from communication lines at proper rates with single-character line buffers.

To meet the need for uninterrupted interchange between user memory and bulk storage, the system includes a data channel, which operates as an independent processor. With this channel, a user program in one of the small banks has access to bulk storage (the Fastrand) independent of the high-speed drum and the central processor. The data channel is activated by an input-output command from the central processor; it then obtains commands and transfers data directly through the memory buffer system independently of the central processor.

It cannot be known in advance in which bank a user's program will be running. Therefore a limited amount of program relocation hardware has been included, in the form of four registers, each holding two binary digits. Thus the user's program can always be written as if it were to be executed from a standard area in memory. Reference to that area by a user's program is automatically diverted by these registers to the area where the program actually resides.

Memory protection registers, which prevent access by users to that portion of memory containing the supervisory program, are also included in the system.

The central processor, in effect, acts as a switch that can connect a user program memory to the central processor itself, to the data channel or to the swapping drum.

Keyed or coded inputs

For the terminals, a Model 33 Teletype was chosen because its keyboard resembles that of a standard typewriter. An input device, now being produced by the Data Equipment Corp. under the name of Datacoder 88, enters graphical or densely coded information.

The prototype Datacoder terminal shown in the photos on the opposite page operates with a Teletype. It sends two 8-bit characters in Teletype code designating the 8-bit x and y coordinates of a point indicated by the cursor, or indicator, when the transmit button is pressed. These coordinates are interpreted by the computer in terms of previously specified commonly used information.

Medication orders, for example, could be handled with the Datacoder terminal. A sheet of paper, divided into a rectangular grid with meanings assigned to each square in the grid, is placed in the Datacoder. One row of squares is assigned drug names like "penicillin," "digitalis," and so on. Another row calls for "1 cc.," "2 teaspoons," and other dosages. Still another specifies "once a day," "after meals," "before retiring," and so on. The doctor, who has written a prescription and wants it checked and recorded by the computer system, calls for the prescription program. This program requests the drugs, dosages, times and all other pertinent data in turn, and the doctor responds by indicating the appropriate squares with the cursor and pressing the transmit button. Greater flexibility is gained by reserving a square to indicate that an entry will be typed in from the Teletype. The Datacoder can also be used for truly graphical input with a resolution of about 1 millimeter.

As the number of users increases, as the number of functions being implemented expands, and as data in the system accumulates, so demands upon the system will increase. The present hardware is only for research, and is not performing any service function in the hospital. However, the experience gained in examining hospital function, in specifying programs, in carrying out this feasibility research program will be very valuable in developing a computer system that will perform specific service functions.

Ultimately, smaller hospitals will time-share the Massachusetts General Hospital system, thus making the talents and experience of a great teaching hospital more readily available to institutions with more modest resources.