A DISTRIBUTED PROCESSING SYSTEM FOR PATIENT MANAGEMENT

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A distributed processing system has been installed at the LDS Hospital in Salt Lake City. This distributed network consists of a central data base and decision making machine interfaced to direct entry terminals located throughout the hospital at various nursing stations, laboratories, and intensive care units. Also interfaced to the central data base system are a series of minicomputers with one or more terminals. The central computer is responsible for data base management, medical decision processing, communications, and statistical analysis of the data base being created by the system. The minicomputer systems are used primarily for physiologic monitoring, local storage and review of data, and for alarming on time critical functions.

The medical computer system at the LDS Hospital in Salt Lake City has been developed over the last ten years. This system, dedicated to patient care computing, was originally designed to be a centralized computer system with terminals for data acquisition and review located throughout the hospital at various nursing stations, laboratories and intensive care units. As the load on the system increased through development of new services and requests for additional terminals, it became apparent that this traditional approach to data processing was no longer adequate to meet the needs of the medical community supported by the system. To increase system capability and reliability a network of minicomputers was interfaced to the existing central computer. In this new system the minicomputers provide dedicated processing, access a central base and communicate with the other minicomputers in the network. The network consists of a central data base and decision making machine (a Control Data 3300) and seven Data General Nova 3 computers which are located in the LDS Hospital's multiphasic screening laboratory, shock trauma unit, coronary care unit, blood gas/pulmonary laboratory, heart catheterization laboratory, the intensive care unit at the University of Utah Medical Center, and the multiphasic screening unit at Cottonwood Hospital, a small community hospital located in Salt Lake City. A Control Data Cyber 17 computer system located at the LDS Hospital is supported by the MEDLAB Company and services the LDS Hospital clinical laboratory.

Figure 1 illustrates the major tasks assigned to the central computer and those functions performed by the remote minicomputers. The first and primary function of the central data base management computer is to control the flow of data into and out of the patient's disc based computerized medical record.

CENTRAL COMPUTER TASKS	MINICOMPUTER TASKS
1. Data Base Management	1. Analog Pre-processing
2. Medical Decision Processing	2. Local Storage/ Review
3. Communications	3. Time Critical Alarms
4. Statistical Analysis	

Figure 1

Figure 2 lists the data base which is currently being captured on a typical patient in the coronary care unit. The data consists of that acquired automatically and/or manually entered. Automatically acquired data includes: arterial blood pressure, pulmonary artery blood pressure, cardiac outputs, ECG data, and laboratory data from the clinical laboratory and the blood gas laboratory. Data which is entered manually includes: demographic data, drugs, IV therapy, x-ray reports, respiratory parameters, temperatures, weights, etc. This data base resides on the central computer and may be accessed by directly interfaced terminals or the minicomputers.

MEDICAL DATA BASE

1. Demographic Data
2. Blood Pressure
3. Surgery
4. Spirometry
5. Diet
6. Blood Gas
7. Drugs and Allergies
8. Height and Weight
9. Sex and Age
10. Admitting Diagnosis
11. Clinical Laboratory Data
12. Electrocardiogram
13. History
14. X-ray Results
15. HELP Decisions

Figure 2

The second function of the central system is to provide computerized medical decision processing. A medical decision system called HELP (Health Evaluation through Logical Processing) has been developed for this purpose. This system has implemented a medical decision language in which medical personnel may easily develop criteria for real time interpreting of laboratory results, diagnosing of diseases, scheduling of procedures and printing of patient treatment protocols. The HELP system has been integrated into the data base system such that a list of decision criteria is associated with each data unit stored on a patient. Therefore, as data is stored in the patient's record, specific decision lists are accessed by the central computer and processed by the HELP interpreter. If a decision results from the storage of data, four different types of actions are possible: 1) An interpretation of the data is stored in the patient record. This interpretation is then available for printed reports or review on terminals at the nursing stations. 2) Setting of an alarm condition indicating that data is outside of the acceptable limits and may be life threatening. This may cause either activation of special alarm lights for the intensive care patient or printout of the alarm at a special nurse alert station for patients in a general medical ward. In the latter instance a nurse clinician will follow up on the alarm with the appropriate medical personnel. 3) Setting of an alert condition. This is similar to the alarm condition, but applies primarily to the pharmacy. Pharmacy alerts consider drug-drug, drug-laboratory, dose and allergy contraindications. If these contra conditions exist an alert is flagged by the computer and followed up by a clinical pharmacist. 4) Printout of patient management protocols which are presented to the medical personnel.

Since many terminals are connected to a single minicomputer system, management of shared communication lines is provided by each minicomputer. Communication between minicomputers is, however, through the central computer. In fact, the primary communication between systems is accomplished by access to the common patient data base. That is, all data from a minicomputer is stored in the central computer data base available to all other units in the network.

Figure 3 illustrates the intercommunications which are available on the system. The figure shows, using the patient as the central figure, the manner in which data flows into the system and the way in which results and alarms are presented to clinical users. Acquisition of the data and review of output can be displayed through the appropriate minicomputer but, as noted above, all data and communications, whether input or output, are routed through the central computer system for both the data base management and HELP decision processing.

The final three major functions of the central system are generalized report generation, data review capabilities and statistical assessments. These capabilities provide common programs for review and reporting of the medical data base and insure the common format of this information. Therefore, similar review formats and statistics are available in all of the intensive care units and nursing stations throughout the hospital.

The primary functions of the remote minicomputers are also outlined in figure 1. The major function of these systems is analog preprocessing of physiologic data. Each system has resident in its memory those programs specific for the environment where it resides. These core resident routines were designed to be multitasked so that simultaneous processing of information from several patients can be accomplished efficiently. Figure 4 lists the types of programs provided for each minicomputer unit. The clinical laboratory computer has not been listed since it is a commercial general purpose laboratory system. For each minicomputer the physiologic processing occurs in concert with time-critical control routines which provide immediate feedback to the medical personnel. Typical of these alarms are those within the rhythm monitoring system where events such as ventricular fibrillation, asystole, etc., are immediately diagnosed and alarm conditions reported to the medical personnel prior to transmission to the central computer system for storage and review by the HELP decision modules.

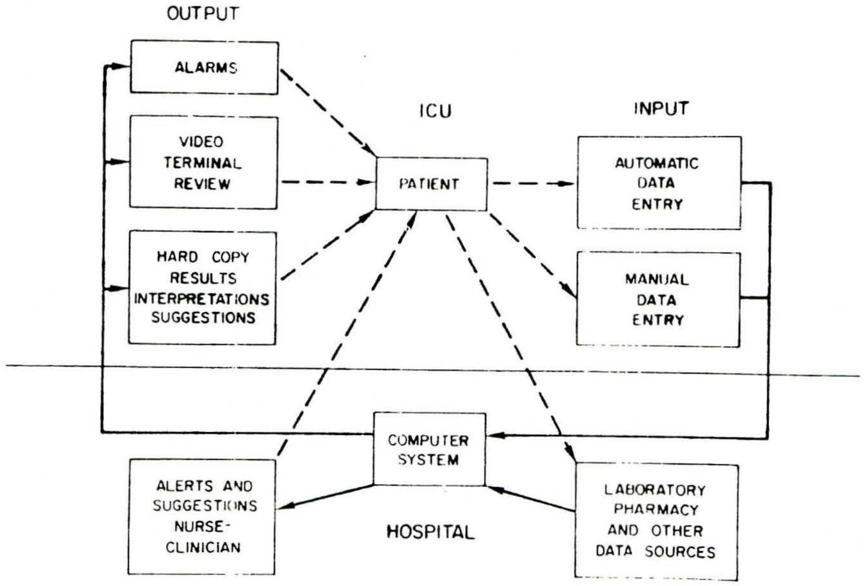

Figure 3

MINICOMPUTER	CORE RESIDENT PROGRAMS
1. CCU	Rhythm Monitoring Pressure Monitoring
2. ICU	Pressure Monitoring Thermal Dilution Cardiac Output
3. Multiphasic	Diagnostic ECG Pulmonary Functions Vital Statistics
4. Blood Gas/ Pulmonary	Blood Gas Analysis Pulmonary Functions
5. Catheterization Laboratory	Pressure Analysis Oxygen Saturation Dye Dilution - Cardiac Output

Figure 4

Local storage and review of data within the various units is also provided by each minicomputer. This feature gives dedicated and complete control over the time-critical functions which provides a useful service in the units during those times when the central facility may be inoperable.

For all terminals connected to a minicomputer, access to either the local core resident programs or those on the central computer is available. Therefore, operation of all programs resident in the central computer system is available at the remote site independent of whether the terminal is connected directly to the central computer or indirectly via a minicomputer. It is transparent to the user whether he is actually using a program that is local to the minicomputer or being processed at the central computer facility.

To further illustrate this system, its use in the coronary care unit will be discussed. As indicated in figure 4 the minicomputer in the coronary care unit is primarily dedicated to physiologic monitoring. The monitoring of ECG rhythm being, of course, the primary concern of the minicomputer. With the insertion of arterial and/or Swan-Ganz catheters, programs are available in the minicomputer to simultaneously monitor arterial, pulmonary artery and wedge blood pressures. The blood pressures may be measured on demand or scheduled at 5 or 15 minute intervals. The rhythm monitoring is a continuous beat by beat analysis with criteria in the minicomputer for numerous alarm conditions. Figure 5 illustrates the alarm conditions currently recognized by the rhythm monitoring program. Upon recognition of any

ARRHYTHMIA ALARMS

1. Asystole (loss of signal)
2. Ventricular tachycardia
3. Atrial tachycardia
4. Tachycardia Alarm
5. Bradycardia Alarm
6. Frequent PVDs
7. Wide QRS
8. Irregular Rhythm

Figure 5

alarm the minicomputer activates an alarm signal causing a bed select light and an audible alarm at the central nursing panel to be actuated. This also produces a direct write-out of the previous 12 seconds of the electrocardiogram. When the nurse responds to the alarm by depressing the selected light, an interpretation of the alarm condition is displayed on the terminal connected to the minicomputer. Displayed together with the alarm conditions is an option to validate the alarm. If the alarm was of artifactual origin, the nurse would then ignore the condition and no subsequent action would be taken by the system. If, however, the alarm condition is validated, the alarm condition and supporting data recorded by the computer are transmitted to the central computer causing storage of this information into the patient's record. Since the HELP decision system is integrated in this data storage the list of possible decisions associated with the alarm condition is retrieved and processed by the HELP system. Assuming the criteria for a management decision is satisfied the central system immediately prints the appropriate management protocol in the coronary care unit.

Summary data is transmitted to the central computer for storage by the HELP system routinely at 15 minute intervals. Similar HELP processing would be performed and appropriate messages printed if required. Manual data are also entered by the nurse or paramedical personnel within the unit. Of particular importance are the logging of drug prescriptions which are reviewed by the medication monitoring system which is, in fact, a list of HELP decision criteria associated with the medication prescription being entered. Other clinical information, including vital signs, drug dose administration, intake and output are entered by paramedical personnel through the terminal. Entry of manual data is accomplished via programs resident in the central data base system.

One of the difficulties in recording the complete medical information on an intensive care patient is that much of it must be manually entered. To capture all of this critical data it has been necessary to hire paramedical personnel to circumvent the queueing problems at the terminal that resulted from having the nursing personnel enter the data. Currently under development in the coronary care unit is a new manual data entry system using micro-processor based hand-held computer terminals. With this system an input port would be available at every patient's bed to which a hand-held input terminal would be connected. A plasma display panel is located over the patient's bed. These input terminals are interfaced to a micro-processor based multiplexor for input/output to the central data base computer. Using the hand-held terminal the nursing personnel rather than the current paramedical individuals would be responsible for input of all manual data currently required in the unit. These terminals have the potential advantage of providing cost-effective parallel data entry and the simplicity of entry resulting from automatic patient and bed identification.

With this computer network during the past 12 month period we have monitored over 800 open-heart surgeries and over 6,000 patient days in the various intensive care units. Currently there is an average of 54 alarms per day. Of these 54 alarms, 24 (44%) occur on patients in the intensive care units. The other 30 alarms are for patients in the general hospital wards. Approximately 2% of all the patients receive an alarm. Of these, only half are receiving optimal treatment. 3.8% of the patients in the hospital receive a medication alert which amounts to 0.65% of all the medications ordered at the LDS Hospital. For 74% of the medication alerts there is compliance by the medical staff with the HELP decision.

We are continuing to explore in each of the units the optimum allocation of resources to determine what set of functions should logically be allocated to the central data base system and those most fitting for the remote minicomputers. Redundancy of data bases and systems for man/machine interface are continuing to be explored in order to obtain the optimum system for active computerized patient management.