A SIMULATION MODEL FOR DATA SYSTEM ANALYSIS

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SUMMARY

The author asserts that designing a data system to support management objectives is, at present, no more than a highly specialized art. This paper then develops the thesis that data system designers can bring their profession closer to a predictive science. Only by adapting for data system analysis purpose analytical tools which make possible prediction and quantification of data system behavior within the management system structure can this be done.

This paper discusses one such tool, a generalized data system model, and describes a technique of simulating dynamic system operation with such a model in order to provide the data system designer insights on the behavior to expect from the data system as it would operate. Some of the benefits possible through such simulation are explored. The paper concludes that the major use for the present of this analytical technique is to test the feasibility of a data system design before acquisition of actual hardware.

I. Introduction

The main object of this paper is to promote the use of simulation techniques for the analysis of data systems that have been designed for management information processing. I will describe our research goals at The RAND Corporation for the development of an all-machine data system analysis model designed for this purpose. Before doing so, I shall present some views on the necessity for employing more objective analytical tools to improve the quality of data system design, and indeed, to bring our profession closer to a science.

A data system designer tries to optimize the use of data processing techniques and equipment as tools of a management system. Accordingly, one must recognize that optimizing the methods and means of information flow is not the objective of the management system. Nevertheless, this subject area is worthy of serious study because of the great potential inherent in present and promised data processing hardware to shape the management system objectives and, therefore, to enhance the concepts of management. It is also a nontrivial fact of life that data processing elements, e.g., data generators, communications devices, computers, are the most costly segments of the modern, complex management systems. Thus, it behooves a data system designer to consider the tradeoffs between contribution and cost for each data processing element in any proposed management information system.

The technique of system simulation has proven invaluable for research and system analyses in many technical fields but has largely been ignored by data system designers. Yet, every data system design proposed to management is in the nature of an hypothesis, since we cannot claim to have studied data system design theory sufficiently to have
established incontrovertible laws in this field. Even when data system design is expertly done, present techniques cannot in any quantitative way assure the "best" system has been achieved, or even that a system will operate as reasonably as can be expected under the time and dollar constraints imposed by management. How can data system designers prove the merit of their assertions if they are often based on visionary concepts, hypothetical equipment, or revolutionary departures from standard procedures? Indeed, in the light of present disenchantment by some managements with their data processing systems, one may ask if data system designers can prove even the feasibility of their handiwork.

I contend that data systems can be modeled to sufficient detail to allow investigation of significant data system design parameters, and that dynamic system operation can be simulated. Data system performance studied through simulation can provide insight on system behavior long before actual hardware acquisition. In this way, modification in system design can be made before it becomes too late to make a change. If data systems are to be adequately analyzed before being cast in hardware, then it would appear that simulation of system operation is required in order to weigh properly how well the uncertainties and the variabilities that usually underlie system design parameters have been accounted for. Furthermore, as long as proven analytical tools are available, data system designers cannot continue to rely on the ipse dixit approach for solving their theoretical problems. Hopefully, our research will determine how well simulation can improve data system design.

II. The Data System

Let me first describe the data system we are considering for representation in our model. The data system is the set of hardware and human resources plus the procedures defined that either generate, record, communicate, process, store or report data and information to prescribed management system entities in a prescribed form and format. Figure 1 is a schematic of a generalized data system, with each of the above functions symbolized by a particular geometric shape. It is not necessary for each of these functions explicitly to occur in the operation of a data system as, for example, when data are generated, recorded, and communicated simultaneously to the processing and storage function. For convenience, the first process is the one represented in the schematic of Figure 1.

III. The Problem of Data System Design

In general the problem of data system design is to create a system which optimally uses the resources selected to do the assigned job. This is not a problem, as stated, except that constraints exist to limit the freedom of choice and utilization of candidate resources. Generally speaking, the major constraints are limitation in the number of dollars and the level of skills which can be applied to effecting the desired solution. Data system restrictions also may be imposed by management system objectives. Finally, even if given the freedom to create the best data system possible, there are the underlying uncertainties in the design parameters with which we usually deal. (See Figure 2.)

A balanced set of data system elements would provide an ideal solution to the data system designer's problem. This means that each system function is provided just the correct types and proper mixes of resources to satisfy each function's requirement for data manipulation. But isn't it true that the stochastic nature of data generation, random equipment failures, and differing data system responsiveness required by various management system sub-functions all mitigate against achieving the desired balance in the data system? Thus, to arrive at a data system design which approaches a balanced system requires study of the system giving due consideration to the effect of these factors on the operation of the system.

IV. Structure and Operation of the Data System Model

The structure of the simulation model proposed in this paper for data system analysis is simply illustrated in Figure 3. From this figure it is seen that all the functions of a data processing system are considered. Each of these must be implicitly or explicitly considered in the data system design, and, therefore, is represented in order that one can evaluate its effect on total system performance and its contribution to system costs. These functions are:
THE DATA SYSTEM DESIGN PROBLEM

OPTIMIZE RESOURCE USE
- EQUIPMENT
- PERSONNEL

CONSTRAINTS
- RESOURCE LIMITATION
  - TOTAL BUDGET
  - SKILL LEVELS AVAILABLE
- MANAGEMENT SYSTEM OBJECTIVES
- UNCERTAIN DESIGN PARAMETERS

Figure 1. Schematic of a Data System

Figure 2. The Data System Design Problem
FUNCTIONS OF A DATA SYSTEM

(1) Data generation
(2) Data recording
(3) Communication
(4) Processing and Storage
(5) Reporting
(6) Report Presentation.

Our model is intended to be general enough for one easily to compare various data system proposals for a given management system. Before analysis, however, comes design. Use of our model requires that a management system be studied in sufficient depth for an information set to be described and a resource allocation made in terms of people and/or equipment required for each data system function. Using the same known (or anticipated) rates of data generation, computation, information growth that led to the design of the data system, and the specifications of the human or hardware resources, each data processing function is simulated. When the complete data system cycle is run through the simulation, or when the number of cycles required for analysis is completed, one can assess the effectiveness of each data system segment as part of the whole data processing system, provided that a severe data system bottleneck has not been exposed during the simulated operation. Costs of a system can be weighed against management system effectiveness for each alternative configuration of data system design. This is done by repeating the analysis using alternative data system design statements. If these alternatives are only in hardware specifications, these new values are the only change required in model input. If an alternative system structure is specified as a change in data flow, the reanalysis is a little more complex.

*When such bottlenecks appear to the analyst to be merely in the number or the quantity of hardware, then (cost constraints allowing) a solution to the design problem is obvious, i.e., get more or better hardware. This solution assumes that the policies of system operation either are not responsible for the bottlenecking, or they cannot be relaxed.

Reanalysis of the system operation would be required with any new hardware assignment in order to insure that the bunching in the data flow had not been passed on to the data system segments which follow.
Simulation Control

The basic control of all events occurring in the simulation of system activity is geared to a master clock which counts the passing intervals of time during the simulation. A management system may include more than a single function. Since the significance of time may vary from one management system function to another, e.g., 15 minutes for inventory control, one-half day for finance, the least significant interval (LSI) of all the functions included in the simulation determines the intervals which the master clock uses in stepping through time.

The model examines all data system events and all equipment simulated, at least implicitly, every least significant time interval of each simulated day's operation. These events include the types and amounts of data input to each data system function, either originating from the function or as a necessary step to another data system function. Demands for equipment are converted from the data input statement, given in terms of message form, frequency and size, to the basic unit of measurement, the LSI, using the given equipment data transfer rates. For example, if a tape-to-card device is not backlogged and a data workload of less than one LSI of tape-to-card time is demanded at the beginning of an interval, a scheduled job will be considered completed and no backlog for this equipment is carried forward to the next time interval.

Simulated Functions

Data Generation. The locations at which system data are generated often represent an important consideration in the design of an information flow system. Thus, the management functions for which data are gathered and the system locations at which they originate are variables in the data system model. Since in many management systems data generate at one location for many functions, such situations shall be anticipated within the data system model.

The characteristics of generated data that must be described to the model by the system designed for each function-location pairing are those which the data system designer must know in order to prescribe a data system structure. These are listed in Figure 4.

DATA CHARACTERISTICS

- MESSAGE SIZE
  - CHARACTERS
  - UNITS
- MESSAGE FREQUENCY
- MESSAGE FORM
- REPORTS REQUIRING MESSAGE DATA
- DATA SYSTEM ROUTES

Figure 4. Data Characteristics
# Resource Characteristics

- Data Transfer Rates
- Capacity Limitation
- Error Function
- Unusual Features

![Figure 5. Resource Characteristics](from the collection of the Computer History Museum (www.computerhistory.org))

A table of resources, characterized as in Figure 5, for each data generation station, e.g., personnel, equipment, prescribed by the designer includes their data transfer rates and makes possible within the simulation a conversion of data characteristics to simulated workload units, expressed as a number of least significant intervals. In addition, we allow an error function associated with each station in order to simulate resource malfunction, e.g., equipment downtime.

Data processing starts with data generation. For any management system function for which the present interval is a significant time interval we determine the amount and type of activity data generated at each location. This activity can be either predetermined for each internal or generated stochastically, depending on how the "message frequency" statement is presented to the model. This yields completely described message groups for each significant function-location pair at every significant time interval of every function. The conversion to LSI units is the next model action. Then, a delay is computed, dependent on the resources assigned and available at each location, describing both the time to generate the message groups and the time to transfer these data from each location to the next data system operation, as prescribed by the "data system routes" statement.

Data Recording. Normally, only those generated data are recorded which are to become part of the requirement for information in the management system being simulated. Recording is defined as arranging data in a form and format required for communication to the processing and storage function of the data system by whatever means prescribed by the data system designer.

The number of recording devices, their locations with respect to the next processing step, and the types of recording devices are variables of data system design. Data handling rates for each device, and the error function assumed for each method of recording are inputs to this model segment. Certain ground rules, i.e., policies, will be required to permit allocation of resources to workload when queues form. Previously generated data routed to the recording function are assumed to have arrived in a single batch to recording stations. Each LSI, the requirement for recording is matched against the availability of the recording device-type that is specified for each message group within a very sophisticated model it would be necessary to assign a failure function for each type of recording device. This error generating function can indicate errors that are either discovered or not during recording process.

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the "data system routes for messages" statement.

By computing an appropriate delay, we simulate the number of intervals required to record messages. Using specified policies, allocation to each available device is made. Devices are committed at the beginning of each least significant interval, so that backlogs are either present or not at each device at the next interval. Again, as in the Data Generation function, the number of intervals required to present recorded data to the next data system step is computed for each message group. This delay is simulated before these message groups are allowed to arrive at the data system function which is planned to be their next destination.

Communication. The similarity between the Communication and the Data Recording portions of the model is obvious. Messages arriving and equipment available are treated identically. All functions are included as part of the model in order to allow for analyses of alternative data systems designs which postulate various mixes of resources within these functions.

Processing and Storage. Activity at a processing center is usually well defined in any management information system which controls some important commercial or military function. Data systems designers concentrate almost entirely on this aspect of the data system. Equipment for each processing run is usually scheduled; as a minimum, a sequence of runs is stipulated, and an equipment assignment for each run can be determined fairly accurately.

The data system model would require as input a list of all devices used in the processing center, both on-line and peripherally, plus the schedule for each device either predetermined or implied by a required sequence of operations. Certain important processing hardware parameters are required model input, such as numbers, data transfer rates, and data densities of input and output devices, and the amount, type and operating rates of directly addressable storage. Finally, we require a description of the input-output and computing overlap capability of the processor, or any unusual feature that affects processing and storage.

Programming parameters, hopefully, can be considered also. These can be stated as estimates of data and instruction storage requirements for programs, and are related to the decision level of the processing required.

The problem as presented to this section of the model is as follows: data are arriving from the generation, recording, and/or communication functions of the data system for storage and processing. These data must be:

1. Stored for later use, e.g., three runs hence, the next day, or weekly cycle.
2. Stored for recall during the next run, i.e., with no setup time required.
3. Immediately processed.
4. Combinations of 1, 2, and 3.

This much about the data and the processing cycle are usually known after preliminary system design: the equipment needed to process the data, the desired product, the required steps of processing, the capacity limitations to storage, and the sets of data needed to effect the end result of processing the data.

Simulation of the processing and storage activity of the data system will include the assignment of message groups to pre-processing periphery equipment, to the main processing steps, and to the reporting function in accordance with the scheduling rules that are system design facts input to the model. The amount of time each machine run requires each piece of equipment in the processing list is computed. This is determined from the size, number, and types of message groups arriving for processing, the equipment's rates of processing, and the error function associated with each piece of hardware in the system.

Equipment bottlenecks in the processing and storage function will be recorded for post-modeling system analysis. Length of slack periods and useful operation will be measured for each equipment. The cost for each equipment can be computed for use in analyzing the effectiveness of the data processing and storage function of the management information system.

Reporting; Report Presentation. For those reports required by system managers which are not direct products of the processing step, the report form and format produced and the operation of equipment proposed can be simulated in much the same manner as in the data recording function. In this way the contribution of specialized data reporting equipment as part of the overall data system equipment mix can be measured and costed.
V. Use of the Model

For what purpose might a data system analysis model be used? Feasibility testing of a proposed management information system design under anticipated operational and environmental conditions is, for the present, the most likely candidate. The fact that total management system optimization may not be possible ought not limit the model’s application. Used early enough in the design stage of a management information system, a feasibility test made possible by use of a simulation model can indicate the way to avoid serious data processing system imbalances before the final commitment for hardware has been made. On the other hand, if the die is cast and a management system is already implemented, simulating data system growth factors can anticipate future data system requirements. Sounder decisions on the type of additional resources to be required, and when these must be on hand can be made on confident predictions of how and where the system will be deficient. We know too little now about complex information system behavior to reject the present objective of a data system analysis model, feasibility testing, limited as it may seem, as an insufficient payoff for our research. On the contrary, we feel that we will achieve the means of better understanding data system interactions through this research.

VI. Measures of Effectiveness

Repeated feasibility testing, with various data processing system configurations assumed as model inputs, provides a means of selecting a particular data processing system design as the best of a set of possible alternatives, provided a measure of effectiveness for data processing systems can be agreed upon. Any means of comparison, even though not guaranteeing optimization, provides a basis for system designers, early in system design, to quantify appraisals of a management system’s effectiveness, which at present can be no more than pure judgment. Confidence to restructure a data system design can be provided by such quantification of analytical processes through the simulation procedure outlined in this paper. We could hope for optimal systems designs were we able to agree on what we mean by data system effectiveness.

It ought not be difficult for data system analysts to agree on the measures of effectiveness that are most important in systems design. It ought not, but it is. We can readily agree that the ability of a system to meet the specified program is extremely important; but whether excess capacity versus system cost, or system cost for work accomplished, or additional system cost to perform the next required increment of system mission is the significant measure of effectiveness of a particular data system configuration is certainly not an accepted standard. One might avoid this problem by saying that management makes the ultimate decision and this is a policy matter beyond the realm of data processing expertness. Be that as it may, with the use of the data system analysis model we can assess the feasibility of a system to perform the mission for which it is designed, and concurrently (1) list the unused capacity within each data system function, (2) cost out the operation under standard contractual procedures (e.g., purchases are in integral units of equipment, rental is on complete or partial shift basis), and (3) with the above data assess, preferably with further simulation, the information system’s capability to take on additional functions. Since the measures indicated in (1) and (2) above will be outputs of the simulation for all the data processing resources in the system, requirement for additional resources necessary to perform any increased workload can be pinpointed to those functions of the information system which appear most likely to need bolstering.

VII. Conclusion

In conclusion, I submit that the research goals outlined in this paper appear ambitious. Yet, one can hope that the process of study itself will enrich our comprehension of the data system design process.

I have no doubt that in time analytical tools will provide data system designers capability to measure, to quantify, and to predict the behavior of important characteristics of the data system. I have no doubt that one day simulation will routinely be a part of the data system design process. We believe that our research may contribute to the early recognition of the value of data system simulation as one tool to enhance the profession of data system design.