1981 Winter Simulation Conference Proceedings
T.I. Ören, C.M. Delfosse, C.M. Shub (Eds.)

INFORMATION SYSTEMS DESIGN THROUGH AN EXISTING SIMULATION APPLICATION

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Abstract

Large scale information systems have been finding increased application in areas of industrial control. Integrated system planning techniques require comprehensive examinations of all aspects of system integration if global optimization goals are to be realized. Simulation provides a methodology whereby potential information and control systems can receive such analysis prior to any system creation. In many cases, an existing simulation can prove to be sufficient for examination of data flow requirements in a general system design.

1. INTRODUCTION

Technological advances in computer hardware have made it feasible to install and implement large scale information systems dedicated primarily for industrial control. The computers in such systems collect, analyze and update data so that managers can obtain an accurate status of the operations at any point in time. Accurate, reliable data can improve the productivity of management and thereby enable more effective control of manufacturing facilities.

The Purdue Laboratory for Applied Industrial Control (PLAIC) recently undertook a project entitled: "Systems Engineering of Hierarchy Computer Control Systems for Large Steel Manufacturing Complexes." The purpose of this research effort was the development, design and specification of a hierarchical computer network capable of implementation in a large steel manufacturing complex. It was anticipated that a complete automatic computer control network would enable American steel manufacturers to regain the competitive edge that they had been steadily surrendering to foreign competition.

The project was divided into seven major tasks, each with a specific subgoal. The final union of these tasks would result in the specifications necessary to implement a fully integrated hierarchical computer network in a major steel manufacturing facility. The relationship between the various tasks and their relative areas of control are illustrated in Figure 1.

It was realized that simply designing a computer hierarchical control network would not necessarily provide the anticipated benefits desired. It would be necessary to re-analyze the production scheduling and control algorithms that would be implemented on the newly designed computer network. In addition, these new scheduling and control algorithms would require some optimal method of data file allocation if the computer network was to be effectively utilized in the anticipated capacity.

This paper discusses the two major tasks associated with the design of the overall computer hierarchy and their integration through the analysis technique of simulation. These two major tasks were:

1) the development and subsequent testing of production planning and scheduling algorithms necessary for optimal utilization of equipment; and 2) the optimal allocation of computer information files necessary to meet systems requirements (i.e. access rates, reliability, etc.).

2. GENERIC STEEL PLANT SIMULATOR

The first task, generation of production scheduling algorithms, required the creation of a generic steel manufacturing plant simulator.

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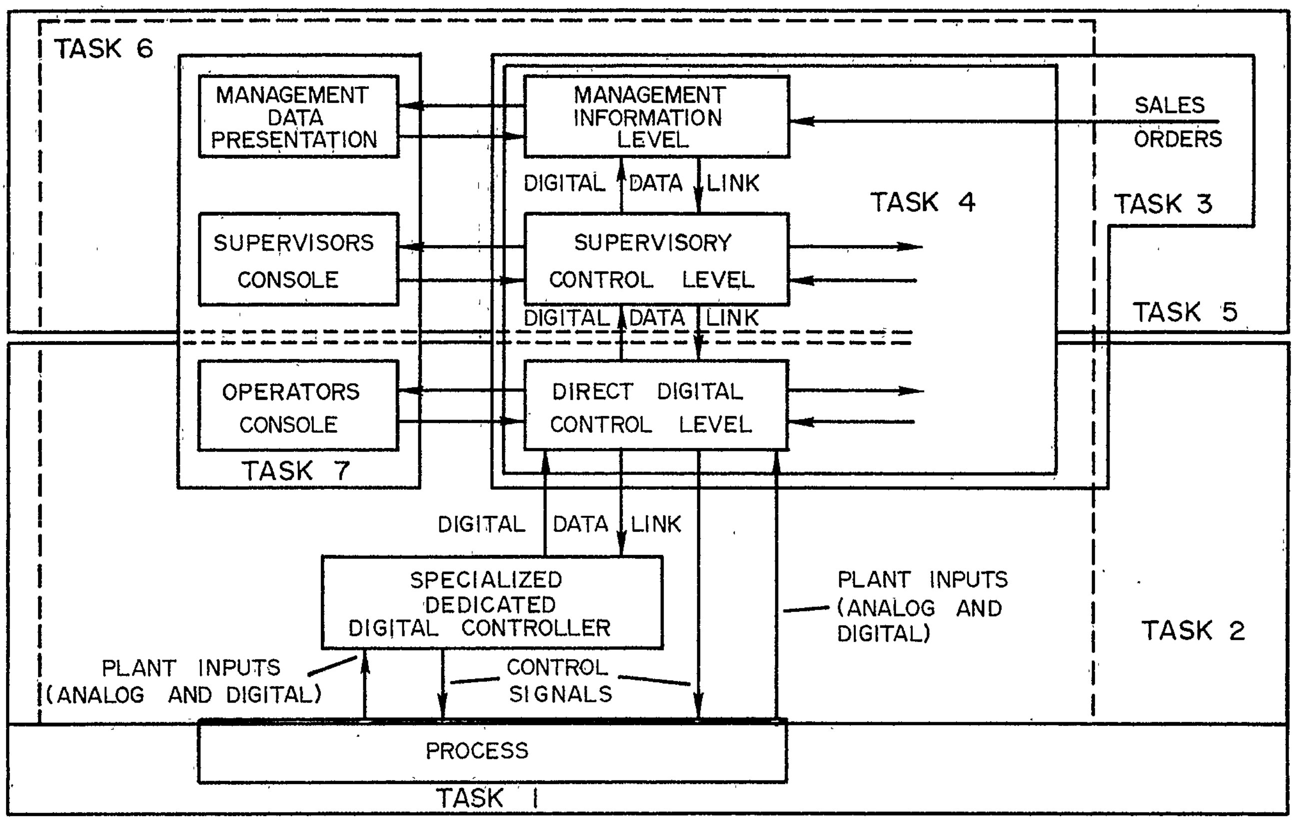

Figure 1. Task Assignments and Areas of Control

Since this project was being supported by the National Science Foundation and several industry sponsors, it was necessary to design production scheduling and file allocation schemes that would function within the environment of any steel manufacturing facility. (i.e. the algorithms developed must be independent of any specific sponsor.)

The task force decided that the simulation model, although independent of any sponsor, should easily represent the manufacturing facilities of any individual sponsor. This necessitated a simulation model that could be altered through data input. Inclusion or exclusion of a specific data card should be the only response necessitated by a user to completely alter some aspect of the manufacturing facility. This design consideration resulted in a modular approach permitting sections of the generic module to be included/deleted as specified by data input. Any steel manufacturer could easily represent his particular facility, including such things as product routing, processing delays, parallel processors, production rates and desired product mix.

2.1 Model Creation

The simulation model was written in the GASP IV (7) simulation language. The model required approximately two man years of effort to complete. During the creation process, reviews and critiques of the model were performed every six months. The reviews consisted of detailed functional analysis by approximately thirty steel manufacturing executives who were participating members of the PLAIC project. The comments of the involved executives were often pivotal in the direction that future modeling efforts undertook. The overall structure of the model can be viewed in Figure 2.

From this figure it can be seen that the model consists of three basic levels:

1. Process model;
2. Load routine model;
3. Master control model.

The cohesive interrelationships between these three models form the basis for the overall simulation package.

The process model consists of the logic necessary to modeling the actual process restrictions associated with the manufacture of steel. Each process is really a modification of the basic queue concept. On data input the user specifies the capacity, processing rates, failure rates, etc. of each individual process. These specifications are then used to create a section of the model that will represent the physical process described. The user also has the option of excluding/including particular parallel processes. For example, he may specify that the raw production capacity will consist of only BOP type furnaces, excluding the open hearth and electric furnace processes. He may also elect to include/exclude the continuous caster capability depending on whether his facility has such a capability or whether he elects to examine the effects of exclusion. To summarize, the process model can be modified to represent any basic steel

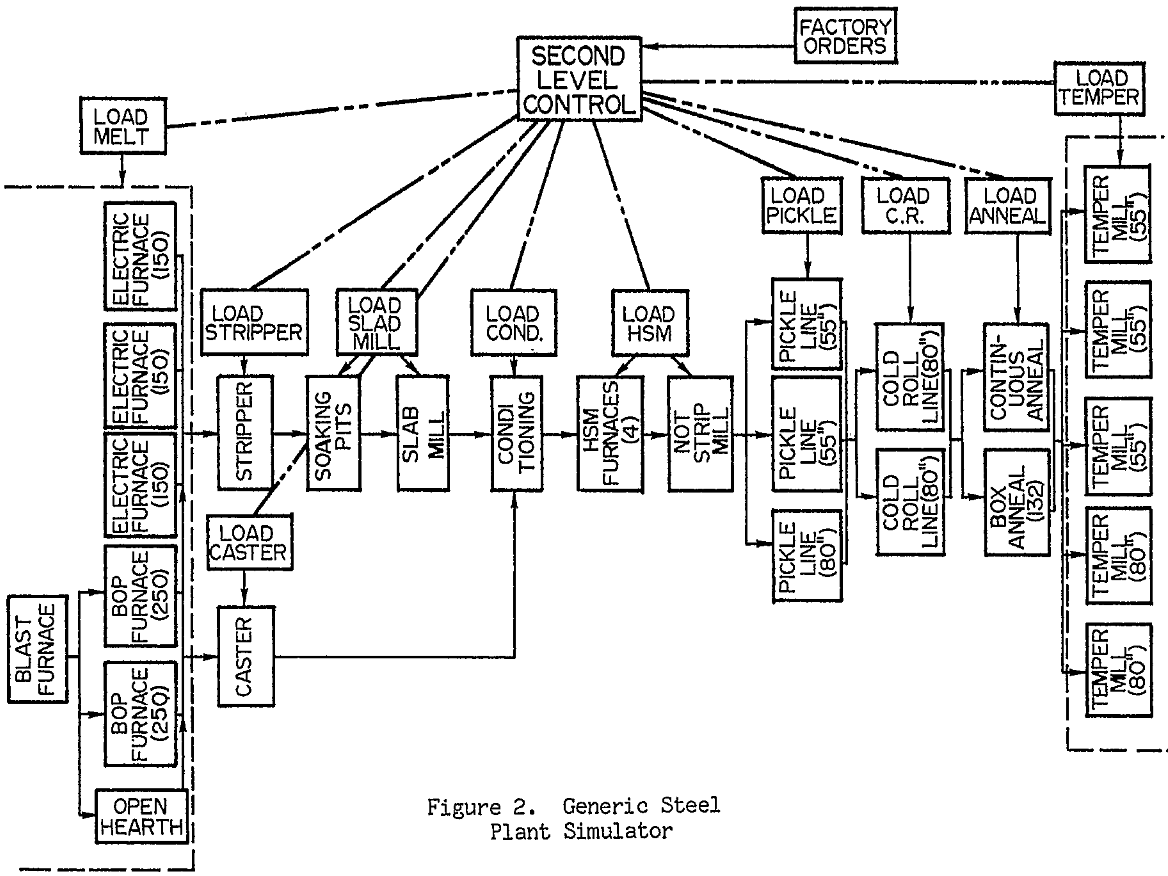

Figure 2. Generic Steel Plant Simulator

manufacturing operation producing flat rolled sheet steel product.

The load routine modules consist of the logic necessary to flow product through the non-thinking process model. These routines are at the next higher level above the process model in the hierarchical structure. Each load routine controls a particular section of the process by ranking the waiting or incoming product in some prescribed fashion. The load modules receive control information from above and institute control actions to the process below. Whenever a unit of product arrives, the particular load module in control decides where the item should be ranked, so as to be consistent with the closed area optimization criteria.

The highest level of the simulation model, the master control module, contains the logic and routines necessary for overall facility optimization. This supremal module communicates with the load modules on a scheduled basis (weekly) and by exception if the anticipated action appears to be of sufficient severity. The master load module handles long range production scheduling, forecasting, master scheduling and weekly production requirements. It performs these functions in a multitude of ways. (3,4) The master module attempts to model the logic associated with a central production control facility. It communicates the production requirements and goals of the central control group to the load modules at the next lower level where the goals will be implemented.

2.2 Model Validation

The simulation model was validated by loading the model with what the PLAIC industry advisory group determined was a basic plant site configuration. (9) The simulation model was configured in this fashion and used to produce production reports at weekly intervals over a specified period of time. Based on these reports the industry experts verified that the simulation model did indeed closely resemble a plant configured according to the input developed by the advisory group.

In addition, the model was implemented at the production sites of two industry sponsors. Similar data loadings of production data were input to the model and compared to actual production reports. These comparisons resulted in the conclusion that the model did indeed resemble a real production facility.

At this time, the model was re-loaded with the basic plant configurations and this structure was utilized throughout the remainder of the experimentations.

2.3 Model Experimentations

The simulation model was designed as the laboratory with which to test the various production scheduling algorithms designed by the project task force. The model was therefore set up in a hierarchical fashion that closely resembled the hierarchical computer network being designed for overall information control. Certain subroutines within the simulation model were designed to permit easy modification based on the particular type of scheduling strategy being tested. The results of the task concerned with the production planning operation have been fully documented and reported in several sources. (3, 4, 5, 6)

To summarize, it was discovered that the newly designed production control strategies could effectively operate within the hierarchical framework of the computer network. The scheduling algorithms could reduce product throughput time and energy consumption. In addition, an increase in productivity approaching 8% was realized. (6) These findings resulted in the statement that nearly $30 million could be saved annually in a plant configured as the basic steel plant and implementing the designed strategies.

A basic assumption of the production scheduling algorithms was the existence of a highly reliable (99.97%), on-line computer system. It was realized that the efficient usage of such an on-line system would require some method of optimally allocating the data files associated with production control. The data must be available with a prescribed minimum delay and with a certain level of reliability. Another task force was then formed so as to develop some methodology for allocating the information files in the manner indicated.

3. OPTIMAL FILE ALLOCATION

The task force assigned the task of optimally allocating the computer files necessary to run the production and information systems was confronted with a serious problem. The information regarding the content of the files could be obtained through interviews and discussions with industry personnel, but the size and frequency of data usage (based on the new scheduling and hierarchical computer configurations) could not be obtained. Since the hierarchical computer system being designed was hypothetical and did not exist in any location, it was impossible for the file allocation task force to obtain the data necessary to test and validate their allocation schemes.

It was then conjectured that since the generic computer simulation model had been developed to model the hierarchical production control scheduling strategies, a completely detailed computer information network, closely resembling the design of the overall project, had been inadvertently created within the model. Since the simulation was written to test real strategies in a general plant environment it had to obtain information necessary for production scheduling from files in hypothetical computers allocated in a hierarchical fashion throughout the generic steel plant model simulation.

The steel plant simulation model was therefore utilized to obtain the information regarding size and frequency of use of data in the anticipated information system.

3.1 Simulation Model Modification

Modifications were made to the GASP IV simulation language that would permit collection of data pertaining to the number of accesses and type of usage of information throughout the production control simulation. Since GASP IV has four basic routines that affect the data files (FILEM, RMOVE, NFIND, AND COPY), the task force modified the GASP IV language to collect statistics regarding the number of times a processing unit would access a particular piece of information. A detection code was also collected regarding how that information was to be used based on the information request unit.

The file allocation model being developed was attempting to minimize the total operating cost while satisfying the network restriction requirements. In the network, it was required that at least two copies of each file be allocated, access delay not exceed certain threshold values and storage limitations of each computer be met. This type of information system, where files are shared by all users in the system is called a distributive data base system. The type of model utilized in this instance is generally categorized as a communication network problem. (1, 2)

As discussed, two types of data were needed: 1) file sizes; and 2) access frequencies (usage). File sizes are determined by the information required by the processing units in the network. These units had been modeled in the GASP IV simulation language in the generic plant simulator. The second type of data needed, access frequencies, were broken into two basic types - query and update. A query is an activity that seeks information from a file without altering its contents. An update transaction is an activity that changes the file content by deleting, adding or modifying records.

3.2 Data Generation

A set of evaluation criteria were determined and specified for each item of data. The items were allocated into specific data records, complete with an estimated number of characters per data item. These records were then combined into the appropriate data files, based on interviews and questionnaires from qualified steel industry personnel.

The modified simulation model was then able to produce the data specifications required for optimal file allocation. The data analysis was performed on the ten basic network nodes described in Table I. These nodes correspond to the structure of the hierarchical computer and information system existing in the generic plant simulator and in an actual industrial setting.

TABLE I
Basic Network Nodes

NODE NAME

1. Main
2. Steel-Making Area Control (Area 1)
3. Hot-Mill Area Control (Area 2)
4. Cold-Mill Area Control (Area 3)
5. Steel-Making Supervisory
6. Continuous Casting Supervisory
7. Slabbing Supervisory
8. Hot Bands Supervisory
9. Cold Bands Supervisory
10. Finishing Supervisory

The simulation model was run several times with different random number seeds to obtain estimates on frequency and usage of data. (query/update) These numbers were then used to produce the overall estimated minumum requirements for the information system. The system was divided into six basic data files. The results of the simulation run pertaining to estimated file size are listed in Table II.

TABLE II
Estimated File Sizes

File Number	Type	Average Records Per Month	Characters Per Month (10^6)
1	Customer Order Status	27,280	12
2	Ingot Status	2,733	1
3	Slab Status	11,768	6
4	Hot Mill-in-Process	6,377	3
5	Cold Mill-in-Process	18,974	8
6	Unassigned Inventory	3,207	2

The data generated from the simulation model also provided extensive statistics pertaining to the number of queries and updates in an average month. These data values are illustrated in Table III.

TABLE III

QUERY/UPDATE TRAFFIC
(frequency/month)

NETWORK NODE	INFO FILE 1	2	3	4	5	6
1	7600	0	1100	100	0	10700
2	6000	0	0	0	0	3700
3	0	5100	0	2700	0	1000
4	0	0	0	0	18000	3900
5	400	2100	0	0	0	0
6	0	2800	0	0	0	0
7	11000	2200	2300	0	0	4000
8	4600	0	500	15600	0	0
9	800	0	0	400	7800	300
10	200	0	0	0	3800	100

3.3 File Allocating

Once the data had been obtained the task force needed to develop an algorithm to efficiently allocate the information files subject to the prescribed constraints. The allocation model was to attempt to minimize the cost of storage and transaction subject to three basic constraints:

1. At least two copies of each file must exist (duplication);
2. Physical storage capacity at the various nodes is limited;
3. User access delay restrictions must be satisfied.

The task force undertook the development of this allocation methodology by designing an efficient heuristic allocation scheme. The workings of this allocation method have been fully documented. (10)

Once the basic allocation scheme had been performed, additional sensitivity analysis test were undertaken. Certain parameters were modified and the effects were observed. It would have been virtually impossible to perform such analysis in finite time were it not for the easily modified simulation model. The generic plant simulator proved to be a very crucial tool in the design of the information system.

4. CONCLUSION

This paper has illustrated an application of a simulation model developed for production control scheduling purposes that was modified and adapted to generate data regarding frequency of information usage as inputs to an optimal file allocation system. This paper has outlined the concepts behind the initial production control simulation design and the optimal file allocation schemes. As illustrated, it has presented an application whereby an existing simulation model has proved to be of greater value than originally intended or anticipated.

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