STUDY OF AN AUTOMATED MATERIALS HANDLING SYSTEM

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ABSTRACT :

The design and implementation of automated materials handling systems is a very complex process. System models can serve a vital role in understanding such installations.

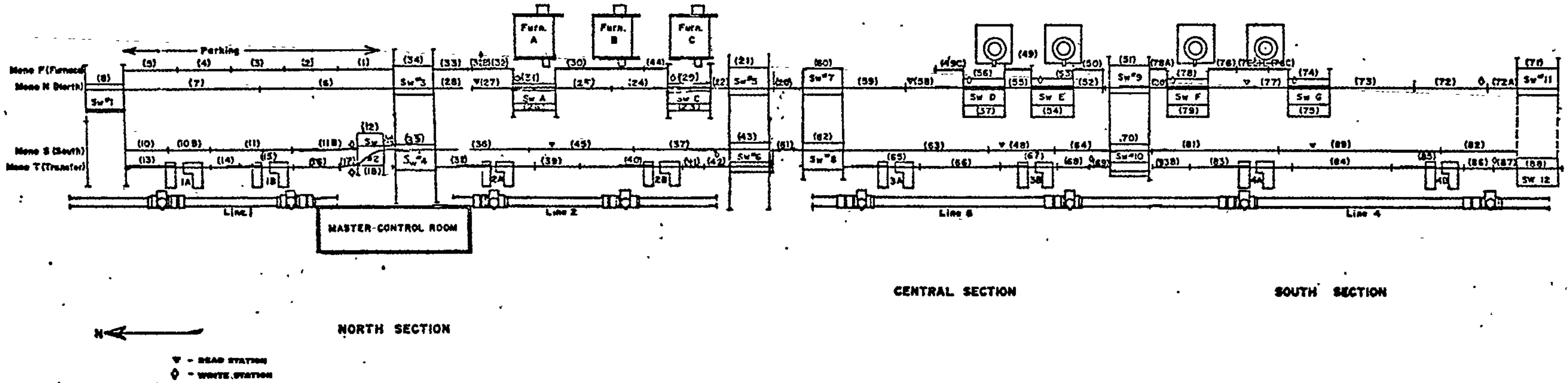
This paper describes a GPSS simulation study of a large automated molten metal carrier system. The simulation model was a major factor in the implementaion process.

An important part of this study was the development and documentation of a technique for the simulation of general automated materials handling systems and assembly line networks.

Both the specific situation and the general methodology are discussed.

In 1974-75 a multi-million dollar automated molten metal carrier system was installed in the foundry of a major automobile manufacturer. The foundry consists of 7 furnaces and 4 mold-lines, each with 2 off-loading points. The system employs a unidirectional monorail network, where 2-ton ladles of molten iron are transported under the control of a bank of three PDP-14 programmable controllers. The network consists of tracks and various switches, as shown in Figure 1.

As of 1977, the system had never been run successfully for extended periods. This was because the system was shut down when an error of any sort occurred. Iron delivery was then continued with a fork-truck system. Neither the system manufacturer nor the user clearly



Parking
Furn. A
Furn. B
Furn. C
MASTER-CONTROL ROOM
NORTH SECTION
CENTRAL SECTION
SOUTH SECTION
N

FIGURE 1.

understood the system failure process, and hence the system was losing credibility. Congestion problems were not being anticipated and there were no operating policies or contingency plans for dealing with system failures.

The foundry had not yet accepted nor paid for the system, and there was a serious question as to whether or not the system was in fact an acceptable proposition. The primary question was the system's capability of delivering iron at rates required to meet production needs. The original contract set delivery rates for several specified configurations (a configuration is a set of furnace to mold-line assignments).

The foundry required a clear demonstration of the system's potential -- but white (no iron) runs of the system were time consuming, expensive and inconvenient. To demonstrate the system's viability, the manufacturer spent several months developing a deterministic FORTRAN simulation. This program was unacceptable to the foundry. Questions arose concerning the effect of changes in furnace to line assignments, as well as the effect of multiple line assignments, system breakdowns, and furnace temperatures. Based on their own experience and the recommendation of an independent consultant, the buyer wanted a thorough simulation study of the system. GPSS was specified as the language to be used since the technical staff of the foundry had some familiarity with its capabilities. They were willing to try the system again if the simulation could demonstrate contract feasibility. At the same time, the system manufacturer was motivated to undertake the study in an attempt to fully debug the PDP-14 codes, to anticipate problems, and to develop contingencies to handle situations such as carrier breakdowns.

At the end of October 1977 the authors were asked to do this simulation study. The task was to model the system and persuade the foundry to undertake another trial with live iron runs. The project began in mid-November and the program was completed a month later. The complexities of the system demanded extreme care in modeling as well as the inclusion of considerable flexibility; but time constraints required proceeding directly with program development.

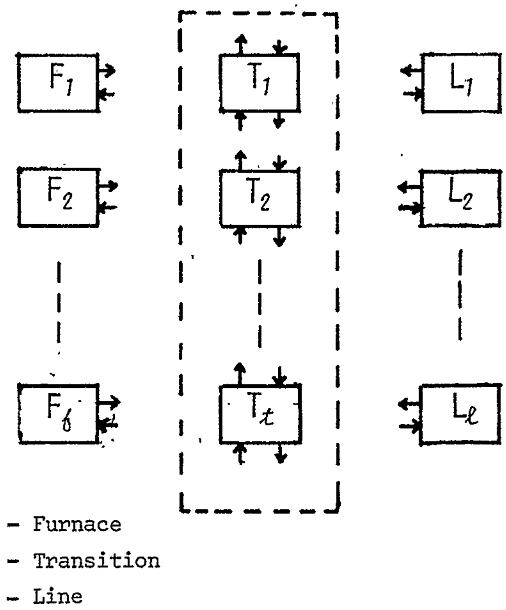
In order to test different configurations and be able to debug the PDP-14 control code, the PDP-14 code's logical structure and flexibility were incorporated in the simulation. The simulation development process formed a feedback loop between the simulation model and the PDP-14 control program. Using these control codes as system documentation, the problem of an incomplete model description was largely overcome.

Thus the simulation was clearly modeling the actual system, rather than anyone's conception/visualization of it. This was of critical importance since the system was not in operation at any time during the study.

GPSS is a block diagram, transaction oriented simulation language [1]. As such it is extremely well suited to the study of automated materials handling networks. The basic transactions in this model are individual iron carrying ladles. The network is viewed as a system of points and routes, Switches, furnaces, and mold lines were modeled as GPSS facilities. At any time, each ladle is assigned to a specific furnace-line combination and hence to a specific route. The model had to allow for easy addition of alternative routes as experimentation proceeded. Iron ladles are picked up and delivered to furnaces and mold-lines, with logic in independent blocks of code. Each route is decomposed into separate transition segments and each of these transitions forms a logical block of GPSS code.

The logical elements of the model are shown in Figure 2. The interconnection of elements is controlled by a set of route and transfer functions. The basic transition block begins execution by assigning the ladle's current position. Actions within the transition block include seizing, preempting or releasing of switches, advancing of travel time, etc. After the transition logic is complete, the iron ladle's furnace and line assignment is used to determine the correct route function. This route function then returns the next postion on the given route. Finally this is input along with the current position to the transfer function yielding the lable of the next transition block. Examples of the code are shown in the appendix.

FIGURE 2.



The hierarchy of route assignments and transition functions is extremely simple and flexible. This approach allows a model to be developed quickly, with modular growth. In this application, the model was executable as soon as the logic for a single furnace and a single line were coded. Transitions were developed one at a time, adding routes to the running model. Thus programming proceeded simultaneously with several programmers, and the overall model structure allowed easy integration of the produced code. This method provides a general approach to the simulation of automated materials handling systems and/or assembly line networks.

The entire coding operation was done with a representative of the system manufacturer present at all times. The responsibility for the PDP-14 control logic was directly with this liason. This facilitated quick answers to questions and provided the manufacturer with an understanding of the coded model and methodology. The simulation was developed directly from the system PDP-14 control code. This forced an extremely careful review of the code and several errors in control logic were detected and corrected during this translation process.

An important problem with the system was that there were no definite operating policies. The system is governed by two sets of state sensing delay timers. Each furnace has an iron requirements timer which anticipates iron needs at the assigned lines and fills ladles at the correct time. This timer was intended to avoid iron cooling if it arrived too soon at the mold line. The second set of timers are located at the lines. These are the line release timers whose role is to ensure that the furnace will be available when the ladle arrives. Both sets of timers were modeled using GPSS user chains. Proper settings for these timers were unknown. There were proposed policies of holding carriers at the lines to avoid congestion and looping carriers which were waiting for a free furnace. These policies were shown to have important impact on the system's ability to meet contracted delivery rates.

The model developed was fairly large (1200 GPSS blocks). In a model of this size, one might anticipate severe run time problems. By careful modeling of transactions, use of short functions and considerable logical breakdown of the simulation, run time was kept to a minimum. Although the assembly phase of the program cost approximately $20.00, execution cost was close to one cent per simulated hour. Experimental costs were kept down by stacking many experiments in a single GPSS assembly.

All parties concerned were comfortable with the model. This confidence derived from following the model precisely through runs by moving ladle markers on a large system schematic in accordance with a trace of the simulation output. Experimentation with the model explored the optimal number of carriers to use , timer settings, and effect of the furnace temperature setting. All runs were initialized with all carriers working, all furnaces full, and all mold lines functioning. The major interest was in long term system stability. To control initialization bias data collection began only after each facility in the model had been visited several times. Trade off curves for each factor were produced and timer settings were explored through the use of response surface methodology. Experimentation also included a full set of contract runs, which played a key role in acceptance by the foundry of further live iron testing. Details of this experimentation have been presented elsewhere [2].

In conclusion, an extremely complex yet efficient and flexible simulation of a molten metal delivery system was undertaken to determine whether or not the system was capable of meeting contract specifications. Through the use of the simulation to modify operating policies, the system was made able to perform as desired. A general modeling approach was developed which allowed the model to be up and running within two weeks, and allowed modular growth to its final state. Computer controlled materials handling systems can be modeled using this approach. Also important was the role of the simulation in debugging the system's control software.

REFERENCES

[1] Schriber, Thomas; Simulation Using GPSS Wiley; 1974.

[2] Schruben, Lee; "Correlation Hypotheses in Simulation Experiments"; Presented at the Los Angeles ORSA/TIMS 1978 Meeting; 1978.

APPENDIX

The following abstracted program segments make the transition approach clear. Every transition is separately coded, as TJDBI below. The code is heavily commented for understanding. Except for the coding of furnaces and mold-lines, the entire program is composed of such components. Other transitions are more complex, involving switch look-ahead actions, acceleration/deceleration, slagging times, etc.

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         .
         .
         .
ROUTE VARIABLE  100+P6*10+P7  ROUTE ASSIGNMENT VARIABLE
*                             ROUTE=100+(10*FURNACE)+LINE.
         .
         .
         .
128    FUNCTION   P4,D5       ROUTE FUNCTION.
4,29/25,35/29,34/34,23/35,4   FURNACE 2 TO LINE 8.
*  PARAMETER 4 HOLDS CURRENT POSITION. FUNCTION YIELDS NEXT POSITION.
*  ROUTE IS 25 -> 35 -> 4 -> 29 -> 34 -> 23
         .
         .
         .
 4    FUNCTION   P5,D4        TRANSFER (POINT) FUNCTIONS.
29,TJDBI/32,TJDCB/34,TJDCD/37,TJDCG
*  PARAMETER 5 HOLDS NEXT POSITION. E.G. IF CURRENT POSITION IS
*  POINT 4 AND NEXT IS POINT 29 THEN TRANSITION IS TJDBI.
         .
         .
         .
*                             TRANSITION FROM POINTS 4('JD') TO 29('BI')
TJDBI SEIZE      SWA          BLOCK THE FURNACE SWITCH FOR A
*  TJDBI  T STANDS FOR TRANSITION
*         JD AND BI ARE ALPHA-CODE FOR 04 AND 29,RESPECTIVELY.
      ADVANCE    27           MOVE ALONG BLOCKS 30,31,32,32B
      RELEASE    FURNA        RELEASE FURNACE A. (SWITCH STILL HELD)
      ADVANCE    17           BEGIN THE SLAGGING DELAY
      RELEASE    SWA          FREE THE SWITCH A
      ADVANCE    18,5         AND COMPLETE RANDOM SLAGGING DELAY
      ASSIGN     4,29         SET CURRENT POSITION TO 29
      ASSIGN     5,FN*3       SET NEXT POSITION ACCORDING TO ROUTE
      TRANSFER   ,FN*4        TRANSFER TO NEXT TRANSITION
         .
         .
         .
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