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ANIMATION OF OUTPUT APPLIED TO MANUFACTURING CAPACITY ANALYSIS

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A general purpose technique for animating simulation output is described. The technique can be implemented using inexpensive hardware and is applicable to many types of simulation models. An example which uses the procedure for capacity analysis in a job shop is presented.

1. INTRODUCTION

Recent years have seen an increase in the use of computer simulation for analysis of manufacturing systems. With this growth has come the realization that the typical methods of displaying simulation output - a printed trace of the events occurring over time or a statistical summary - are often inadequate. Simulation users and language designers are beginning to explore the potential of computer graphics in model verification, analysis, and presentation of simulation results. This use of graphics may be application-oriented or general purpose. The application-oriented approach typically involves building a pictorial model of the system of interest, and mapping the simulated output into this representation. The general purpose approaches include animating the flow of entities through a network model, as is done in $IDEF_2$ (Pritsker) and generating histograms, pie charts, graphs, etc., as is done in many languages including SIMAN (Pegden) and $IDEF_2$.

The application-oriented approach can provide a very realistic animation which is easily understood. For example, material handling devices can be shown moving parts on the shop floor. However, there are disadvantages to building such a graphical model. A great deal of programming effort is required and typically the model is applicable to one system or a class of closely related systems. Sophisticated graphics hardware or software may be needed for display of the simulated system.

In contrast, the general purpose system usually displays a static summary of results rather than an animation showing change over time. Where animation is used sophisticated hardware or software may again be required, and the representation of the system may be much less familiar to an audience.

This paper describes a general purpose animation package for displaying simulated output which can be run on a variety of hardware, including a standard CRT terminal with a graphics character set such as the DEC VT100. The package is an outgrowth of research in capacity planning and shop floor control. The original intent was to display work in process as it changed over time to evaluate order release and scheduling methodologies. However, the package can also be used to display discrete-change variables for many types of simulation models.

2. ANIMATION OF OUTPUT

2.1 Description of the Model

The objective in constructing the animation package was to provide a general purpose representation of the state of a simulated system over time which would allow rapid determination of system capacity and utilization. In addition, it was desired to simplify the process of creation and modification of graphical models.

Because of these considerations, the number of entities in a subsection of the model (queue, conveyor, transporter, resource, etc.) is represented as the height of a bargraph. The user defines, labels, and locates the bars and specifies a minimum and maximum number of entities for each. Figure 1 shows a small model with two queues and two machine types: drills (quantity one) and lathes (quantity two). The queue behavior will be observed between the limits of 0 and 5 entities and 5 and 50 entities for queues 1 and 2, respectively. Machine utilization will also be displayed.

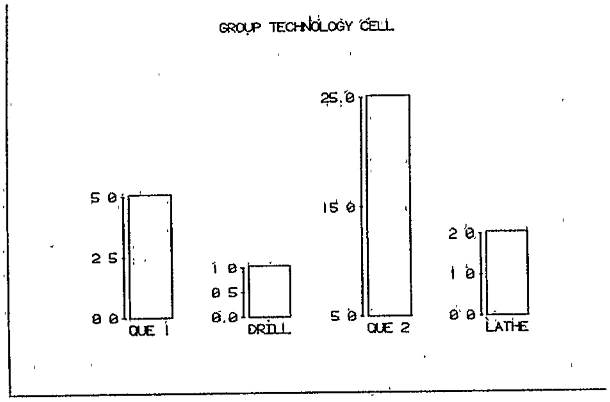

Figure 1: Model Setup

Results of a simulation analysis of this system are depicted by filling the bars to the appropriate levels. The animation is performed as a series of discrete time steps; the status of the system at the end of each step is displayed. Length of the time step is determined by the modeler. Figure 2 shows the state of the system during one step of simulated time. All machines are busy, 1 job is waiting for the drill, and more than 25 for the lathes. The symbol above the bar representing queue 2 indicates that the specified maximum display quantity for that queue has been exceeded.

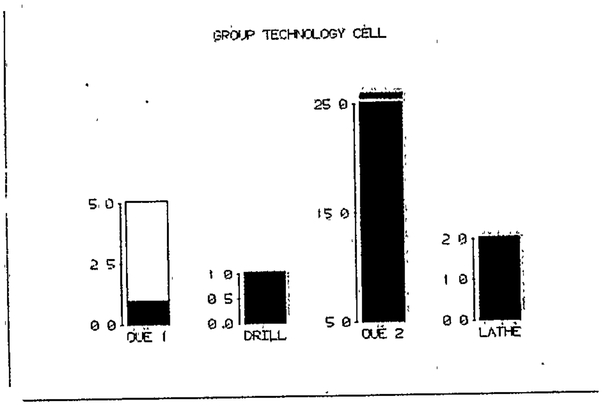

Figure 2: System Status Display

2.2 Data Requirements

A file of information is required for each type of data (queue, resource, etc.) that is to be animated. At each change of status, the simulated time and the new status (number of entities or value of a variable) must be recorded. This information is then replayed by the animation model.

The model presently is used for simulations built in the SIMAN language. Using SIMAN, the required files can be generated merely by specifying a field on an input card. However, the animation can be used with other simulation languages which provide the facility to generate such data files, or which allow user-coded program inserts for these purposes.

2.3 Animation Model Creation

Although creation and placement of the bars is a simple process, it rapidly becomes tedious if repeated viewing of a model under different experimental conditions is required. Therefore, the animation package includes options to:

- create a model
- save a model
- retrieve a model
- change a model

The user can create a library of models which can be recalled, updated, and saved as desired. For each model the information saved includes its title, the number of bars, the time step, and each bar's label, placement and minimum and maximum range.

3. EXAMPLE

A model of a small job shop was constructed using SIMAN. The shop contains five machine groups with one to three similar machines in each group. Work in process is held at the machine group for the next operation and is not assigned to a particular machine in that group until the machine becomes available and the job begins its processing.

Using SIMAN, the status of the system and statistics on system performance were collected for 3375 simulated time units. Part of the statistical summary is contained in Figure 3. Machine groups 1 and 5 had very high utilization and correspondingly longer queues. Standard deviations on queue size are large, suggesting that queue lengths fluctuate considerably. It is not obvious from this summary if the fluctuation is cyclic or if it results from a growth in the amount of work in process. Further, the change in the number of waiting jobs for the entire shop over time cannot be determined from this information. For example, one queue might increase while another is depleted or both might increase simultaneously depending upon the job mix and the order release policy in effect.

An animation of the data (Figure 4) reveals the time-varying behavior of the shop. In this figure, the queues are drawn above their respective machine groups; the six pictures represent different time periods for the simulated shop. It is readily apparent from this figure that the amount of work in process is increasing as time passes. Queues 3 and 4 seem to be relatively stable, while the others tend to increase over time. This suggests that the order release strategy should be modified to favor those orders requiring substantial processing by machine groups 3 and 4, and to delay orders which would further increase congestion in the remaining machining areas. The effectiveness of such a modification could also be evaluated using the animation model.

DISCRETE CHANGE VARIABLES

NUMBER	IDENTIFIER	AVERAGE	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	TIME PERIOD
1	QUEUE 1	0.1827E+02	0.1174E+02	0.0000E+00	0.4200E+02	0.3375E+04
2	QUEUE 2	0.4709E+01	0.5658E+01	0.0000E+00	0.2000E+02	0.3375E+04
3	QUEUE 3	0.2666E+01	0.2650E+01	0.0000E+00	0.9000E+01	0.3375E+04
4	QUEUE 4	0.2450E+01	0.3540E+01	0.0000E+00	0.1200E+02	0.3375E+04
5	QUEUE 5	0.4198E+02	0.2594E+02	0.0000E+00	0.8400E+02	0.3375E+04
6	MACH 1 UTIL.	0.2966E+01	0.2860E+00	0.0000E+00	0.3000E+01	0.3375E+04
7	MACH 2 UTIL.	0.1618E+01	0.6942E+00	0.0000E+00	0.2000E+01	0.3375E+04
8	MACH 3 UTIL.	0.7659E+00	0.4234E+00	0.0000E+00	0.1000E+01	0.3375E+04
9	MACH 4 UTIL.	0.1439E+01	0.7231E+00	0.0000E+00	0.2000E+01	0.3375E+04
10	MACH 5 UTIL.	0.2890E+01	0.4891E+00	0.0000E+00	0.3000E+01	0.3375E+04

Figure 3: Shop Capacity Statistics

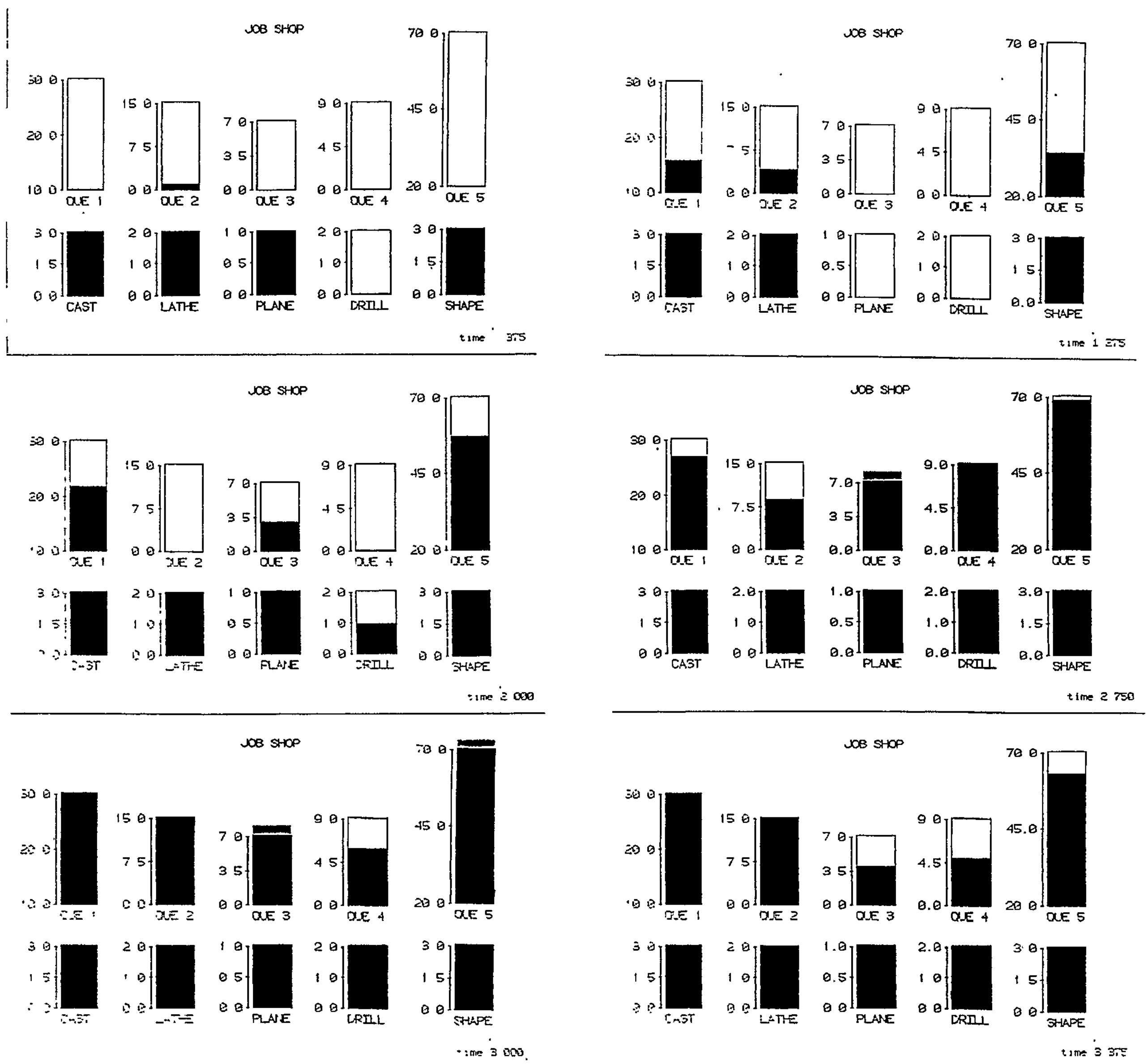

Figure 4: Animation of Shop Capacity

4. SUMMARY

The animation package described in this paper is useful in obtaining an overview of fluctuations in work in process in a simulated shop for capacity analysis purposes. In addition, it can be used for a wide variety of simulation models to display any variable which changes in discrete steps over time.

A limitation of this approach is that it provides an overall series of snapshots of the system, but no detail on the individual elements. It is impossible to ascertain, for example, which jobs are currently in the work center queues. Thus, the package is not suitable for applications such as interactive scheduling, which require such information.

A planned addition to the package is the capability to stop the simulation, change certain parameters associated with the model, (queue priority, for example) and then continue running the model, but under the new conditions. This feature would require a close link between the output animation package and the simulation language used for modeling and thus would have a more limited application than the package as described in this paper.

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