Proceedings of the 1983
Winter Simulation Conference
S. Roberts, J. Banks, B. Schmeiser (eds.)

SIMULATION, MANUFACTURING AND GRAPHICS

Van B. Norman
Manager Operations
AutoSimulations, Inc.
562 South Main Street
Bountiful, Utah 84010

The simulation of material movement, equipment location, operating and scheduling rules is a powerful tool for the design of state of the art automated manufacturing facilities. This paper describes a software system (AutoGram) that allows the designer of an automated manufacturing facility to easily construct a simulation model by graphically describing the system to be modeled. The designer selects from a menu of standard manufacturing and material handling components. These include such devices as robots, machine tools, conveyors, cranes, automatic guided vehicles and storage systems. For each device the designer may use default performance characteristics or he may specify the important operating parameters of the device. From the designers facility definition a GPSS/H (General Purpose Simulation System) model is automatically produced. Output from the GPSS simulation is displayed graphically as an animated representation of the facility. The designer can observe on the graphics display an animated picture of the manufacturing facility in operation under various simulated operating conditions. Complicated simulation models can be produced in 1/10th the time of traditional techniques.

1. INTRODUCTION

The revitalization of American industry involves a conversion from discrete manual manufacturing systems with large material inventories to facilities with continuous material flow through each of the production steps, resulting in smaller material inventories. The major goals in the design of such automated manufacturing systems are:

(1) Reduced labor costs.

(2) Increased machine utilization.

(3) Reduced work in process inventories.

The design of automated systems to achieve these goals is challenging. The cost for such systems is high. The implementation of state of the art systems involves multiple equipment suppliers and complex "systems" technology. Because of the cost, implementation schedules, and the totality of the commitment, new systems must work the first time. These large investments must begin to pay off in the first days of operation.

Simulations of new manufacturing systems that are conducted during the concept stage of planning and design provide a means of testing initial designs. These models can produce designs and system implementation plans that will work from day one. Simulations can reduce the performance risk for new facilities and technologies. The simulation model does not in itself provide an optimization of the plan. The model is a tool that enables the intelligent designer to apply his skills in an iterative process of testing and changing the design. This optimization should occur before a commitment is made to expensive hardware procurement.

Through comprehensive modeling a detailed analysis of the proposed system under a variety of operating conditions can be accomplished. By use of the latest programming techniques a model can be developed quickly so that the acquisition of analytical data will not delay the project. Changes can be made to the model quickly to evaluate design revisions needed to improve system performance.

The implementation of new factory systems involves extremely high costs as well as a level of expertise that many companies do not have. A true automated factory may consist of distributed numerical control machine tools, robots, automatic guided vehicles, automated storage and retrieval systems and conveyors. The overall system is generally controlled by a central mainframe computer which communicates through a hierarchy of minicomputers to individual microprocessors that control station operations. A typical system may cost $10 million. However, it is usually possible to break up the overall system into parts for a phased implementation where the cost of each phase is supported by an incremental return on investment and the financial capacity of the company involved. Simulation models can be developed to test not only the final factory configuration but each installation phase.

In the last five years the application of simulations to factory planning has become widely accepted. There are many dramatic examples of how simulation models identified design problems and allowed the testing of fixes before hardware procurements were made. Simulation models have also been used to find and examine problems in existing systems. Software technology and trained personnel have become available to reduce the cost and time needed to obtain simulation models and to greatly improve their accuracy.

2. AUTOGRAM DESCRIPTION

ASI's proprietary software system AutoGram allows designers of manufacturing and material handling systems a quick and easy method of determining important operational parameters of existing or planned systems. AutoGram allows a designer, using state of the art computer graphics equipment, to describe the types of equipment to be studied and their physical and logical relationships. Users of AutoGram are able to evaluate system designs by reviewing computer simulation reports and by viewing simulated system operations as a computer simulation is executed. Equipment and material are dynamically moved on the graphics screen as the computer model logically moves items based upon the designers system definition.

AutoGram consists of four software components:

(1) AutoGram-Describe. This software subsystem allows the designer to describe the manufacturing system to be studied. The designer selects from graphical menues using the graphics tablet standard manufacturing and material handling components. When the designer selects a component, he places on the screen. The designer optionally modifies with keyboard entries the operational characteristics of the component. This software creates a graphic database of the described system and a logical model of the system in a very high level manufacturing modeling language called AutoMod.

(2) AutoMod. AutoMod is a descriptive language and compiler expressly designed for modeling manufacturing and material handling systems. System descriptions written in AutoMod are compiled into easily transportable standard GPSS/H programs.

(3) GPSS/H. GPSS/H is a industry standard general purpose simulation language. GPSS/H is acquired from its creator Wolverine Software of Alexandria, Virginia.

(4) AutoGram-Display. This software system uses the graphics database and system status information from the model to create a dynamic image of the system being investigated. System designers will be able to see such scenes as; computer guided vehicles moving material between machine tools, pinch points and queue build ups on conveyor systems, and storage/retrieval machines operating in warehousing and WIP applications.

AutoGram has extensive capabilities to model most industrial facilities. The focus of AutoGram is on the movement, control and processing of material. Modeling consists of defining what moves, when it moves, and how it is moved. AutoGram has a proven library of control and scheduling algorithms that optimize the utilization of equipment and personnel.

Standard AutoGram components include definitions of:

(1) Conveyors including live roller, power & free, tow lines, belt conveyors, and monorails.

(2) Storage Systems including conventional racks, high rise storage systems, carousels, and flow racks.

(3) Automatic Guided Vehicle Systems (AGVS).

(4) Industrial Trucks.

(5) Machine Tools and Robots.

(6) Cranes.

(7) Flexible Manufacturing Systems.

(8) Conventional Warehouses and Distribution Facilities.

3. AUTOGRAM OPERATION

The operation of the AutoGram/AutoMod systems is shown in figure 1.

(1) AutoGram is a software system that accepts a graphics tablet and keyboard definition of a manufacturing or material handling system and translates the description into an AutoMod model of the system. Standard vector representations for display of typical manufacturing and material handling devices have been developed and stored on disk. The animated display portion of AutoGram reads a component status file written by the GPSS/H simulation model and displays the animated simulation results.

(2) AutoMod is statement translator which translates definition statements into GPSS/H models. The translator has extensive error checking of definition statements. Custom GPSS/H model subroutines are developed as prototypes for standard manufacturing and material handling components.

(3) A subroutine library of standard GPSS/H routines for each material handling component is available. The standard routines have the capability to control material handling equipment based upon user defined priorities and proven algorithms.

The GPSS/H models are extremely accurate; such features as real world collision avoidance for wire guided vehicles and partitioning of long conveyor drives into actual tracking zones are included. Field experience with model results indicates that models predict system performance within 5%.

As an example of model detail, AutoGram distinguishes between three types of pallet conveyors; transport, accumulation and queuing conveyors. Each type of conveyor must be modeled differently because in high performance systems their unique characteristics affect system performance.

Transport conveyor is used to model chain and chain driven live roller conveyors. These conveyors are characterized by long drive sections with logical windows larger than the pallet length. Induction of a pallet onto the conveyor requires that an empty window be exactly positioned in front of the induction location. All pallets on the conveyor are physically locked together, the distance between pallets cannot increase or decrease. If the last pallet on the conveyor cannot advance then the conveyor must stop and all loads behind the stopped load will have an increased transit time.

The difference between accumulation and queuing conveyors has to do with the movement of pallets from the conveyor when multiple pallets are queued. In accumulation conveyor when the first pallet in queue moves forward all pallets behind also begin to move. However in queue conveyor the second pallet will not advance until the first has moved one pallet length forward. This creates the effect an empty window rippling back through the pallets in queue.

4. SAMPLE SIMULATION PROCEDURE

To create a simulation model of a automatic guided vehicle system the following steps would be followed.

(1) Define the area to be covered by the simulation giving the X and y dimensions. AutoGram displays a grid over the simulation area on the graphics screen.

(2) The definition of the vehicles involves the specification of the following parameters.

Number of Vehicles and their starting locations.

Vehicle horizontal speed including acceleration and deceleration (optional).

Vehicle load and unload times (optional).

Vehicle capacity, number of loads (optional).

Selection of vehicle display shape and line color for display (optional).

(3) The definition of the vehicle guidepath involves the specification of the following items.

The definition of all guidepath control locations. These are locations where the vehicle may stop, where the vehicle may be assigned a destination or where route selection is made. A control location is a logical guidepath resource used either for vehicle routing or for vehicle

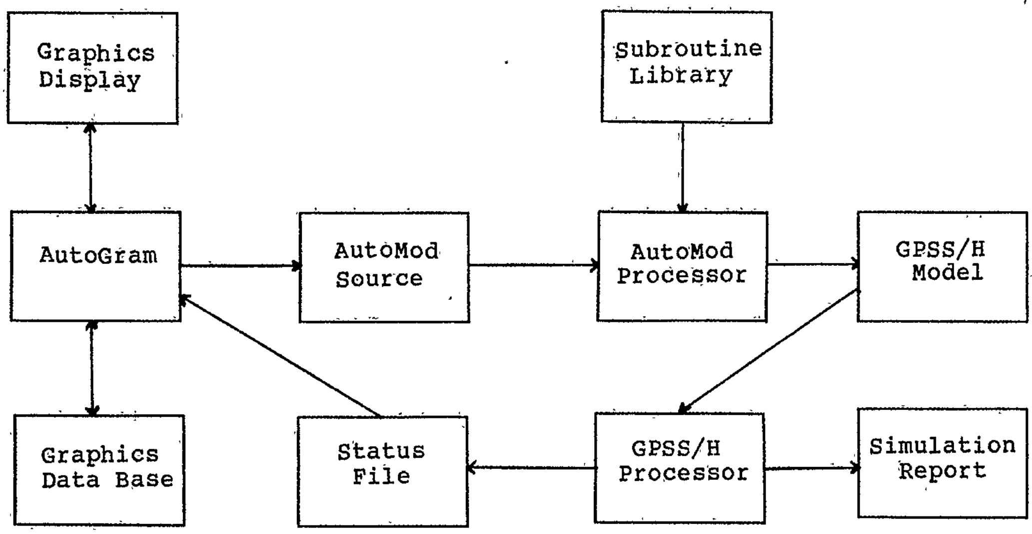

Figure 1: AutoGram Operation

control to prevent vehicle collisions. For the control locations the modeler must define the rules when the locations are claimed and released by the vehicles. For each control location the modeler must define all the possible control locations that are accessible from the current location.

(4) Load Creation Locations. For each control location where loads are initially picked up, the modeler must define the load arrival rate and the paths through storage the load will travel. Multiple load types may be defined.

(5) Load Termination Locations. For control locations where loads leave the model, the modeler must define the time after the load is set down by the material handling until the load disappears.

(6) Interfaces to other types of material handling equipment.

AGVS control algorithms have a profound effect on system performance and the number of vehicles required to perform a given level of activity. In general, the critical system resource in an AGVS is the empty vehicle. Loaded vehicles are under assignment and are committed. Empty vehicles can do one of three things. One, stay where they are. Two, go pick up a load that is ready for movement. Three, move to another control location or parking location before deciding what to do.

AutoGram has several standard vehicle scheduling algorithms designed to be compatible with various AGVS types.

5. AUTOGRAM OPERATING ENVIRONMENT

The following is the operating environment for AutoGram.

Software:

(1) UNIX (Berkley version 4.1).

(2) GPSS/H from Wolverine Software.

AutoGram is entirely written in C. While we have not attempted to move it to another computer system, it should be relatively transportable.

GPSS/H was selected as the modeling language because of our extensive experience with the language, its significant performance advantages over other general purpose simulation languages and its powerful extensions allowing customized reports without dropping to a subroutine call.

Hardware:

(1) DEC VAX 11/750 with 1 Mbyte of memory.

(2) 160 Mbytes of disk storage. About 20 Mbytes are required.

(3) 1600 bpi magnetic tape unit.

(4) 10 - RS232 9600 baud serial ports.

(5) E&S PS300 with 1 Mbyte memory, color display, graphics tablet, and operator control dials.

The Evans & Sutherland PS300 is a high performance, self contained interactive graphics system. A typical PS300 work station consists of a refresh random vector CRT, a set of eight control dials, a combination keyboard / function button unit, and a data tablet. The custom graphics control processor separates the PS300 from other graphics systems. There are several individual units within this controller, including a Motorola MC68000 microprocessor. The microprocessor can address up to four million bytes of memory. The control processor is also the device that interfaces to the host computer and interprets the interactions coming from the various PS300 peripheral devices. Within the controller is a display processor that reads the contents of memory . The graphics controller performs all the required transformations including clipping, perspective computation, viewport mapping, depth queuing and other operations without host computer overhead.

The PS300 has the unique capability to allow the dynamic modification of the designers view of the system as the simulation continues. Three control dials allow the rotation of the system about the x, y and z screen axes. The graphics tablet can be used to indicate the point in the system to center the viewport and a dial can be connected to a scale function so that the operator can zoom in on an area, to observe it in greater detail.

6. CONCLUSIONS

The use of sophisticated computer graphics with simulation models is a new development. The use of graphics equipment offers the following advantages.

(1) Reduced model development time. Designer interaction with graphics system allows the automated system designer to create a model in about 1/10th the time that it would require if traditional simulation languages were used.

(2) Traditional computer simulation techniques give the system designer system statistics based on averages over several hours of simulated time. This data is essential for determining system performance. However, to observe transients and gain confidence in the correctness of the model a graphical display of the system in operation is required.

(3) Engineering teams have found a video tape of a simulation graphical display a effective tool for end user and management presentations.