一般論文

AN INSTRUCTIONAL FMS LABORATORY: DESIGN, APPLICATION AND SIMULATION

박양병

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Abstract

This paper describes the instructional flexible manufacturing system(FMS) laboratory facility at Virginia Polytechnic Institute(VPI) which is directed at problems and issues in the design, implementation and control of computer integrated manufacturing systems. It begins with a configuration and an operational description of FMS laboratory facilities. Next, relevant curricula in manufacturing systems design and control, which can use the FMS laboratory for instructional purpose, are introduced, A computer simulation can be used as an excellent tool for analysis prior to implementation of FMS as well as an on-going improvement tool. A brief survey of simulation languages is lastly included.

I. INTRODUCTION

Society of Manufacturing Engineers in America defines flexible manufacturing system(FMS) as follow: A FMS is an individual machine or group of machines served by an automated materials handling system, that is computer controlled and has a tool handling capability. Because of its tool handling capability and computer control, such a system can be continually reconfigured to manufacture the wide variety of parts. This is why it is called a FMS. The FMS is considered as the technology to adapt to rapid changes in machining tasks and small production quantities.

Since the first installation of FMS in 1967 in Great Britain and the U.S.A., the number of installations in other countries such as Japan, Germany, U.S.S.R. were followed. This development coincided with an abrupt increase in NC-machine applications. In recent years, it is clear that Japan is moving ahead in its applications[7].

The FMS laborartoy at Virginia Polytechnic Institute(VPI) and State University has been created to provide a facility for instruction and research in the integration and control aspects of the computer based manufacturing technologies[12]. Within the laboratory are an automated storage and retrieval system (AS/RS), two 3-axis CNC milling machines, two industrial robots, an automated conveyor

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system, a machine vision system, automated identification equipment, programmable logic controller(PLC), and a network of personal computers.

This paper describes the instructional FMS laboratory facility at VPI which is directed at problems and issues in the design, implementation and control of computer integrated manufacturing systems. It begins with a configuration and an operational description of FMS laboratory facilities. Next, relevant curricula in manufacturing systems design and control, which can use the FMS laboratory for instructional purpose, are introduced.

In order to minimize a risk in aquisition of FMS, computer-aided planning aids can be used for planning of FMS. A computer-based simulation has been recognized as an excellent tool for analysis prior to implementation of FMS as well as an on-going improvement tool [11]. Thus, a survey of simulation languages is lastly included.

This paper will serve as a good reference for the construction of FMS laboratories in universities as well as real flexible manufacturing cells (FMCs) or FMS in industries. In addition, it gives a brief knowledge of computer simulation softwares available in the current market.

Ⅱ. FMS LABORATORY

1. System Configuration

The laboratory consists of a machining workcell, an assembly/kitting workcell, an AS/RS, a S/R machine, a pickup/delivery station, an operator workstation, and a conveyor system to interconnect the other facilities. A network of personal computers is used to control the system. Figure 1 shows a layout of the various equipments in the laboratory. Since the focus of the laboratory was to be specifically directed at issues in systems integration and control, every effort was made to make the system hardwares compatible with respect to their functional characteristics.

The machining workcell consists of two CNC milling machines and an industrial robot that performs the loading and unloading operations of the parts in the workcell. The assembly/kitting workcell, consisting of an industrial robot and an assembly jig and fixture, performs three functions: kitting, assembly of machined parts and restocking of raw materials(blanks) into gravity feed bins.

The two milling machines are DYNA 2200 3-axis milling machines. The milling machines are capable of three axis contouring motion with an optional fourth axis index table. Programs, irrespective of their original form, are translated into the DYNA languages and downloaded into the machines through the laboratory computers. While the machines are capable of machining aluminum and other soft metals, machining wax is used for most laboratory work.

The robots are an IBM 7545 robot and an IBM 7547 robot and are both programmed in the AML/E programming language. The robots are capable of 6-axis contouring motion. The programs are downloaded into the robots

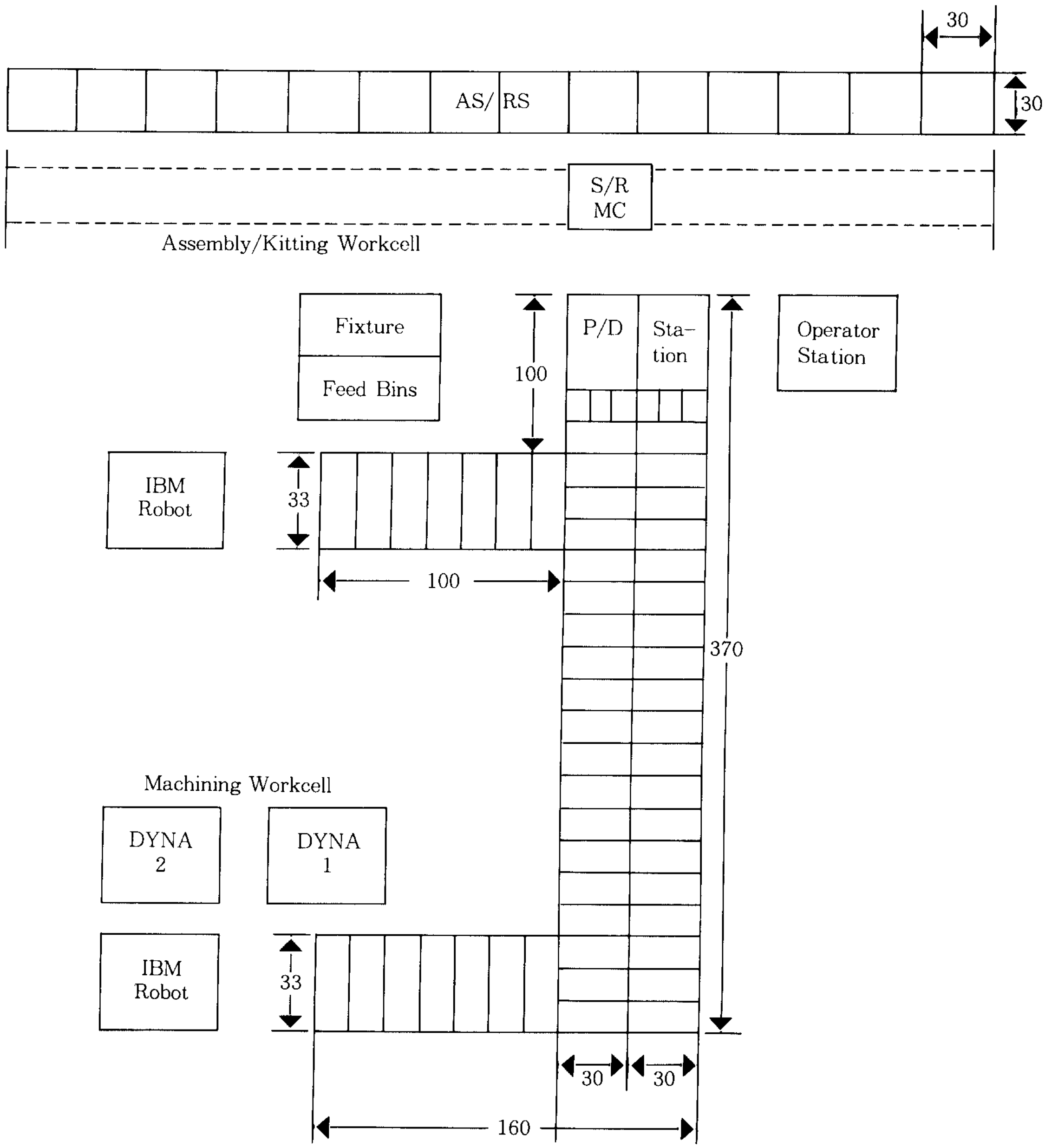

Figure 1. Layout of FMS Laboratory

through the laboratory computers.

The AS/RS, located at one end of the laboratory, is a single asile, single bay storage structure serviced by fully automatic S/R machine. It has a capacity of 84 slots for storing empty pallets and kitted pallets for machining. A pickup/delivery station, along side each other, links the AS/RS to the conveyor system. All parts are stored in standard size pallets which are made of aluminum and fit into the slots in AS/RS. Figure 2 shows the views of pallet. The same pallets are used for transporting materials on the conveyer. The pallets are bar coded to facilitate tracking of the products as they move through the system.

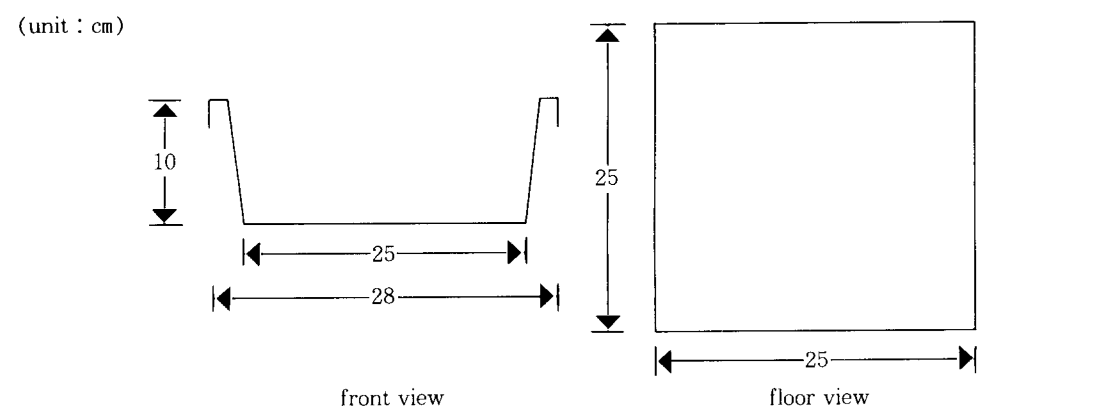

Figure 2. Views of Pallet

The S/R machine that was assembled at the machine shop in VPI, is capable of handling one pallet at a time on a dual command cycle and simultaneous horizontal and vertical travel at constant speeds. Communication between the workcell controller and the S/R machine is possible only at the pickup/delivery station or when the S/R machine is not in motion.

The conveyor system consists of a dual 2-way roller conveyor between the workcells and two single bidirectional conveyors perpendicular to the dual conveyor leading to each workcells(the holding areas). It has stationary single entry and single exit points of the accumulating type. That is, when a pallet reaches the exit point, the conveyor continues to move, sliding under the stationary pallet and eventually bringing the following pallet up against the first pallet, so on. The traveling speed is constant. Pallets are removed first in and first off the conveyor.

The AS/RS and the conveyor are directly controlled by a Texas Instruments 565 PLC which is linked both serially and through discrete, parallel input/output lines to the workcell controllers. The PLC can be programmed with a relay ladder logic structures. The laboratory computers are used to develop control logicl which is then downloaded into the PLC via the TISOFT programming package.

The General Electric Optovision Ⅱ machine vision system, located above the pickup/delivery station, is used for inspecting the pallets that pass the station. The machine vision system utilizes the Vision Programming Language. Many actuators and sensors are used in the system. The operator workstation is located adjacent to the delivery station and followed by an outgoing conveyor.

The computer control network is organized hierarchically and the control of the system is accomplished at three levels: system, workcell, and device, as shown in Figure 3. Three DOS based AT personal computers serve as workcell controllers and control the assembly/kitting workcell, the machining workcell, and the handling/storage workcell consisting of AS/RS, the conveyor system and the machine vision system, respectively.

The machining workcell controller is linked serially to the robot and the two CNC machines. Additionally, a limited amount of parallel connections are provided between the workcell controller and the three mechanisms. Since the parallel input/output facilities of the CNC machines are quite limited, workcell sensors and actuators are connected to the robot input/output ports.

The assembly workcell controller is linked to the workcell robot both serially and discretely. Various workcell sensors and actuators are connected directly to robot input /output ports. Typically, the serial linkages are provided for program down loading and modification while the parallel linkages are provided for real time control and for operations monitoring.

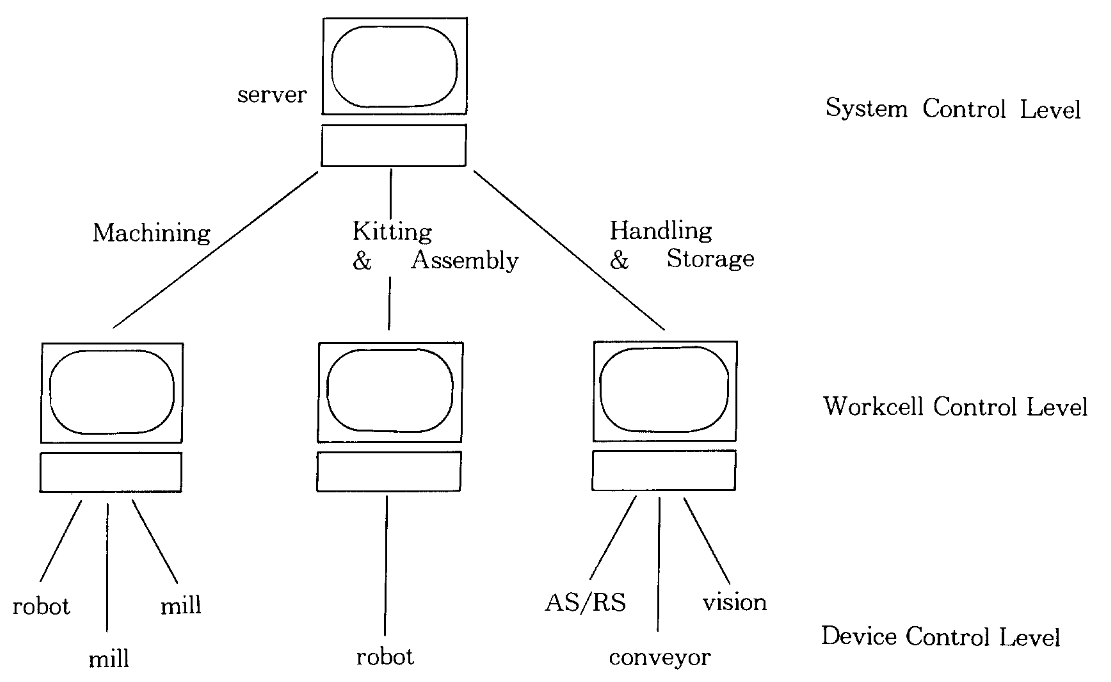

Figure 3. Control Network

The three workcell controllers are connected to a system control computer through the STAR Local Area Network. the system controller is a UNIX based personal computer. Communications with the workcell controllers is done by using shared file stroage. The UNIX based system controller is used to permit true multitasking operations to be performed for system control, operator interactions, and management report preparation.

2. System Operational Description

The FMS laboratory is designed to operate with one operator. The system programming and control functions are accomplished by a network of personal computers and an industrial programming controllers. The operation of the FMS can best be understood by following the steps taken by a typical product while it is in the system.

First, an empty pallet or a kitted pallet is taken out of storage in AS/RS and delivered to pickup station where the conveyor system transports it to the assembly/kitting workcell or the machining workcell depending on the status of the pallet. The machine vision system verifies that the pallet contains proper parts in the desired locations when the kitted pallet passes the pickup station.

For the empty pallet, the robot at the assembly/kitting workcell creates a "kit" by removing the raw parts necessary to make a product from the gravity part feeder and placing them on the pallet. This operation is referred to as kitting. During the operation, raw materials are replenished to the (feeder in the assembly/kitting cell by the robot when the feeder) is below the safety stock level. The robot is continuously informed of the current level of the feeder through the computer network. The kit is then taken to the machining workcell or back to storage depending upon the status of the machining cell. The machine vision system verifies the desired locations of the parts when the pallet passes the delivery station.

For the kitted pallet, the robot at the machining workcell removes the parts from the pallet and place them on the CNC milling machines. After the parts are machined, they are returned to the pallet. The pallet is then returned to the assembly/kitting cell where the parts are assembled into a product by an assembly robot using an assembly fixture.

The finished product is placed back to the pallet and transported to the delivery station. The operator in the workstation then removes the finished product and the empty pallet is taken by S/R machine back to storage in AS/RS or the pickup station in order to transport it to the assembly/kitting workcell, depending upon the status of the assembly/kitting workcell.

Ⅲ. CURRICULA APPLICATIONS FOR THE FMS LABORATORY

Since the function of the FMS laboratory is to explore issues in system integration and control, the application of (the laboratory must logically follow the graduate courses in) manufacturing automation technology. These courses will concentrate on both the integration of the various hardware devices and the control of the system as a whole. Some of the simpler exercises may be the problems such as the linking of the milling machines to the workcell controller or the different natures of the three wokcell controllers. Other project assignments may be specifically directed at enhancing the existing system. Group projects are highly recommended.

Many undergraduate courses can also use the facilities in the FMS laboratory. The first courses in which a student encounters the laboratory complex may be the ones for manufacturing processes which include the exercises in basic numerical control and robotics programmings. Next, a method engineering related course has an exercise in machine balancing that involves the use of the CNC milling machines as the production machinery for a specific product. Students gather cycle time data and design an appropriate production method for producing the product under various expected levels of demand.

Basic industrial automation courses make extensive use of the facilities in the laboratory for basic instruction in manufacturing systems automation technology. These courses include fundamental exercises in numerical control programming, programmable logic controller applications, machine vision data processing, and industrial robot applications.

Additionally, the FMS laboratory can serve as a demonstration vehicle for other courses which address issues in systems design and control. This not only includes classes in industrial automation, but courses in simulation, production planning and control, and plant layout and materials handling. Finally, the laboratory can be used by the graduate courses related to the manufacturing systems design to illustrate various aspects of system design and control.

Ⅳ. SURVEY OF COMPUTER SIMULATION LANGUAGES

There are numerous simulation software packages available that can be used for analyzing the manufacturing systems. The simulation languages may be classified into two major categories: general purpose simulation languages and data-driven simulators.

General purpose simulation languages provide a modeling orientation in which a model of the system is constructed. They can model a wide variety of systems and perform any type of analysis. But they require programming expertise. Some of them contain special features for modeling manufacturing systems. Data-driven simulators allow a user to model specific systmes with little programming effort. There is no need to learn a language at all as the information representing a simulation model is provided as an input data rather than a series of programming statements. They are usually menu-driven and some have been designed specifically for simulating manufacturing systems or a specific area within manufacturing systems. These two types of simulation softwares may be capable of simulating either discrete systems, continuous systems or a combination of the two types of systems.

Besides the two types of softwares, there are several other types of softwares available, mainly from the academic field and some of which are under research. These softwares aid in the consturction of simulation program by freeing the user from much of programming effort. There have been two major approaches in the academic field: program generators and model description languages. Matthewson [6] provides discussion on program generators. Overstreet and Nance[11] provide discussion on the model description languages.

The current state-of-the-art in simulation is to bring artificial intelligence and expert systems into simulation methodology[8]. Object-oriented programming techniques[2] will most likely be used to facilitate this current research. In fact, object-oriented languages have already been used to develop simulation packages or simulation language tools. These run on a variety of computers, ranging from workstations to minicomputers to mainframes.

It is the intention of the survey in this paper to focus mainly on the use of general purpose simulation languages and data-driven simulators that can be run on personal computers. The survey gives a brief description of some of the more popular softwares being used specially for the design and evaluation of manufacturing systems in industry. A list of the two types of softwares is presented in Tables 1 and 2 with the vendors supplying the softwares and their introduction dates. Most of the information in the tables were obtained from the current available literatures[1, 3, 4, 5, 9, 13].

1. General Purpose Simulation Languages

The Table 1 shows a list of general purpose simulation softwares that can be run on personal computers with DOS as the operating system and require no additional compiler. They all feature interactive input modes and debugging, graphics capabilities and animation display concurrent with the simulation run, except INSIGHT. Standard icons are available to represent the system being modeled or users may create their own icons.

The benefits of animation include effective communication and presentation of the results of the model as well as ease of debugging and model verification during the construction of the model. It also lends itself well as an analysis tool during the running of the model. Some of the softwares listed in Table 1 have a seperate system for the animation and graphics, indicated by a slash. Those with more elaborate graphics include CINEMA, PCModel, SIMPLE 1, SIMGRAPHICS, SLAMII/PC, and GPSS/PC.

SLAMSYSTEM is actually a supporting software that provides SLAMII with an environment that integrates the softwares supporting the range of tasks performed in a simulation project using the Microsoft Windows interface. It can be used to build SLAMII models graphically and textually. Multiple tasks may be performed in parallel while a simulation is executed in the back-

TABLE 1. GENERAL PURPOSE SIMULATION LANGUAGES

SYSTEM	VENDOR	DATE INTRODUCED
1) AutoMod(2e)*	AutoSimulations, Inc. 655 Medical Drive Bountiful, Utah 84010, USA	1990
2) CADmotion (previously PCModel/GAF)	Simulation Software Systems Inc. 2107 North First Street, Suite 680, San Jose, CA 95131 USA	1986
3) GPSS/PC	Minuteman Software P.O. Box 171 Stow, MA 01175, USA	1984
4) GPSS/H	Wolverine Software Corp. 4115 Annandale Road Annandale, VA 22003–2500, USA	1988
5) GPSSR/PC and GPSS	Simulation Software Ltd. 760 Headley Drive, London, Ontario, N6H 3V8 Canada	1981
6) INSIGHT	SysTech Inc. P.O. Box 509203 Indianapolis, IN 46250, USA	1986
7) PCModel	Simulation Software Systems Inc. 2107 North First Street, Suite 680, San Jose CA 95131, USA	1984
8) SIMAN/CINEMA	Systems Modelling Corp. 504 Beaver Street Sewickley, PA 15143, USA	1983
9) SIMNET v2.0	SimTech Inc. P.O. Box 3492 Fayettville, AR 72702, USA	1988
10) SIMPLE**	B.-D. Becker IPA-FhG Schlosstr. 68 D-7000 Stuttgart 1, West Germany	na
11) SIMPLE 1	Sierra Simulations & Software 303 Esther Avenue Campbell, CA 95008, USA	1985
12) SIMSCRIPT Ⅱ.5 /SIMGRAPHICS	CACI 3344 North Torrey Pines Court La Jolla, CA 92037, USA	1962
13) SLAM Ⅱ/PC SLAMSYSTEM**	Pritsker Corporation 1305 Cumberland Ave. P.O. Box 2413 West Lafayette, IN 47906, USA	1984 1988

*runs on Macintosh Ⅱ

**requires Microsoft Windows　　na – not available ground. It also allows a user to compare outputs from scenarios graphically and textually and view multiple windows of graphical outputs at a single time.

CADmotion and SLAMSYSTEM permit the import of screens from other software packages like AUTOCAD as a background layout. SIMPLE 1 has a frame grabber to capture images created with one of the popular PC graphics programs like Dr. Halo and DeluxePaint Ⅱ. GPSS/PC has a postprocessor which makes 3-D animation based on a previously recorded GPSS/PC animation.

Special material handling systems constructs have been developed in some simulation softwares. SIMAN has special material handling features for modeling transporters which include automatic guided vehicles (AGVs) and conveyors. SLAMII, through a Material Handling Extention, also provides a capability for modeling transporters and storage areas.

Another important feature in a simulation software is its statistical capability. Among those with more extensive statistical capabilities is INSIGHT. The emphasis in INSIGHT is on providing nonprocedural methods of statistics collection, a wide variety of statistical input mechanisms for reflecting a broad range of input models, and variance reduction techniques, being targeted at users with little statistical background.

The capability of a simulation model to run on mainframes, minicomputers and microcomputers without modifications is a very useful feature which is also becoming common to quite a number of languages. GPSS/PC, INSIGHT, SIMAN, SIMSCRIPT Ⅱ.5, SIMNET 2.0, and SLAMII have this feature. In addition, interfacing with general purpose language like FORTRAN or C for modeling flexibility is also a plus when modeling complex systems. This feature can be found in GPSS/H, INSIGHT, SIMAN, SIMPLE 1, and SLAMII.

Memory size is crucial when modeling complex systems on the personal computer. To handle this, PCModel and CADmotion support Expanded Memory Specification and SIMSCRIPT Ⅱ.5 uses dynamic memory allocation for most of its constructs which saves the user from having to be concerned about the size of the data elements.

2. Data-Driven Simulators

All the simulation softwares listed in Table 2 have graphics and animation capabilities. Some of the softwares have a seperate animation system, indicated by a slash. Constructing a model involves entering data instead of programming codes. They are most suitable for users who need to build a model fast and who do not have much simulation programming experiences. In return, these softwares are usually more restricted in their capabilities to certain application areas.

The softwares listed in the table have a manufacturing orientation with special features for modeling particular aspects of manufacturing like scheduling, capacity planning or FMCs. In particular, STARCELL, written in

TALBE2. DATA DRIVEN SIMULATORS

SYSTEM	VENDOR	DATE INTRODUCED
1) FACTOR	Pritsker Corporation. 1305 Cumberland Avenue P.O. Box 2413 West Lafayette, IN 47906, USA	1985
2) Genetik	Insight International Ltd. 2 Robert Speck Parkway, Suite 750 Mississauga, Ontario L4Z 1H8, Canada	1982
3) HEI RTCS	HEI Corporation 350 E. Randy Road Carol Stream, IL 60188, USA	1981
4) HOCUS*	P-E Inbucon Modelling Division 4118 Murphy's Run Court Hampstead, Md 21074, USA	na
5) MAST/BEAM	CMS Research Inc. 600 South Main Street Brooklyn Center Oshkosh, WI 54901, USA	1980
6) Micro SAINT/ Animation	Micro Analysis & Design Inc. 3300 Mitchell Lane, Suite 175 Boulder, CO 80301, USA	1986
7) MIC-SIM/VIEW	Integrated Systems Technologies Inc. 350 South Lowe, Suite C Cookeville, TN 38501, USA	1986
8) Model Master	G.E. Corporation P.O. Box 8106 Charlottesville, VA 22906	1983
9) ProModel (formerly PROMOD)	Production Modelling Corp. 1834 South State, Suite G Orem, Utah 84058, USA	1986
10) SIMFACTORY	CACI 3344 North Torrey Pines Court La Jolla, CA 92037, USA	1986
11) SIMIS Ⅱ	SD2 GmbH Emil-Figge-Str. 75 4600 Dortmund 50, West Genmany	na
12) STAR CELL	H.J. Stendel & Associates 1654 Sherman Avenue Madison, WI 53704, USA	1987
13) SYSTEM BUILD/ PC	Juli Jensen 2500 Mission College Blvd Santa Clara, CA 95054-1215, USA	na
14) WITNESS SEE WHY	ISTEL Corporation 60 Mall Road Burlington, MA 01803, USA	1986 1980
15) XCELL+	Pritsker Corporation 1305 Cumberland Avenue P.O. Box 2413 West Lafayette, IN 47906, USA	1986

*runs on Unix(286/386)

Turbo Pascal, focuses on the design and evaluation of the flow line of FMCs. It also assists in the evaluation of impact on cell performance from changes in product mix, demands, and job input sequences. FACTOR is a simulator for evaluation of scheduling alternatives and sensitive analysis of material handling systems. MAST, WITNESS, ProModel, and SIMFACTORY have special constructs for modeling material handling systems. The XCELL+ software has facilities to model AGVs and power-and-free conveyor systems. The other softwares also have some material handling features but not as extensively.

There two softwares that have been developed from general simulation languages. SIMFACTORY is written in SIMSCRIPT Ⅱ.5 that provides users with the ability to quickly model factories without program coding. The other software, WITNESS, is developed from SEE WHY.

Ⅴ. CONCLUSION

This paper described the development of an instructional laboratory facility which is directed at problems and issues in the design, implementation and control of computer integrated manufacturing systems, through the introduction of the FMS laboratory at VPI. This laboratory can be extensively used by the courses related to the design and control of the manufacturing systems.

Computer simulation is a powerful tool for the design and evaluation of FMSs. Some popular simulation software packages were presented with their important properties, among over 50 simulation products oriented towards the analysis of manufacturing systems. This survey will help the analyzer in selecting a suitable simulation software to use.

This research will serve as a good reference for

(i) the construction of FMS laboratories in universities as well as actual FMCs or FMSs in industries.

(ii) the curricula developments related to the design and control of manufacturing system and their use of FMS laboratory facilities.

(iii) the selection of simulation packages to use for the analysis of manufacturing systems.

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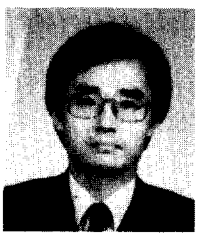
저자소개



저자(박양병)는 현재 경희대학교 산업공학과 부교수로 재직중이다. 한양대학교 산업공학과에서 학사, Pennsylvania State University에서 석사, Oklahoma State University에서 박사학위를 취득하였으며, Northeastern University 산업공학과조교수, 그리고 Virginia Tech.객원교수로 근무하였다. 주요 관심분야로는 컴퓨터통합생산(CIM)시스템의 설계와 분석이다.