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MANUFACTURING SIMULATORS

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ABSTRACT

Simulation modelling has been identified as one of the most powerful techniques available for the analysis and design of complex manufacturing systems. A number of manufacturing simulators have been designed in an effort to make it easier to use the simulation approach in the manufacturing environment. This paper will attempt to describe and evaluate the characteristics of some of the available manufacturing simulators as well as possible ways to alleviate some of the inherent disadvantages. This paper will also report on the preliminary design philosophy and specifications of a manufacturing simulation program generator (FACSIM) presently under development.

OPSOMMING

Simulasiemodellering is een van die mees kragtige tegnieke beskikbaar vir die analise en ontwerp van komplekse vervaardigingstelsels. In 'n poging om die gebruik van simulasiemodellering in die vervaardigingsomgewing te vergemaklik is 'n aantal vervaardigingsimulators ontwikkel. Hierdie artikel sal poog om die eienskappe van sommige van die beskikbare vervaardigingsimulators te bespreek en te evalueer. Tegnieke wat moontlik gebruik kan word om die effekte van die inherente nadele van simulators te verminder sal bespreek word. Die voorlopige ontwerpfilosofie en spesifikasie van 'n vervaardigingsimulasie programgenerator (FACSIM), wat tans ontwikkel word, sal ook beskryf word.

INTRODUCTION

Manufacturing systems are becoming more complex in nature resulting in a need for more effective systems analysis techniques. Simulation modelling has been identified as possibly the most powerful and most often used general purpose technique to provide in this need [4,6,7,8,9,14,16]. Recent developments in the theory of simulation modelling as well as simulation modelling software have made it possible to model very complex systems [4,7,17]. However, the time, effort, expertise and experience needed to successfully develop and use such complex models are still relatively extensive and represent at present probably the most significant constraint limiting the use of simulation in the manufacturing environment [6,9].

Using a general purpose programming language, such as FORTRAN or PASCAL, for building a model of a manufacturing system may provide the analyst with extreme modelling flexibility but will require extensive knowledge and experience of simulation theory as well as computer science while the model development time may be prohibitively long. General purpose simulation languages, such as SLAM or SIMAN [17], provide the model builder with a structured simulation modelling approach but these languages are not designed to be problem specific and therefore all the available features of the language have to be understood in general context and then applied in modelling a specific system.

Various efforts have been and are being made in an attempt to make it easier to develop and use simulation modelling in the manufacturing environment [9]. These may include features such as microcomputer based languages, graphical input capabilities, animation, model management utilities, special pre-processors, expert system based user interfaces and interactive environments [1,2,9,14]. Furthermore some of the available general purpose simulation languages, for example SIMAN, GEMS and MAP/1, have been extended to include special manufacturing and materials handling modelling capabilities [17].

Another attempt at making manufacturing simulation easier for the user consists of the development of manufacturing simulators [14,17]. These simulators are dedicated toward the development of simulation models within the manufacturing system domain and therefore may result in a loss of flexibility and general applicability but at the same time a significant decrease in the level of expertise and the amount of time necessary to develop such a model may be expected.

MANUFACTURING SIMULATORS

A number of manufacturing simulators have been developed and are commercially available [17]. Some of these simulators tend to concentrate on the modelling of a specific type of manufacturing system, for example flexible manufacturing systems or materials handling systems, but other simulators may be applied to the modelling of manufacturing systems in general.

Commercially available manufacturing simulators

Table 1 provides a summary of some of the characteristics of three of the more important commercially available microcomputer based manufacturing simulators.

The MAST/SPAR/BEAM simulator [17]

The MAST (Manufacturing System Design Tool) simulator consists mainly of a very high level specification language dedicated toward the simulation modelling of computerized manufacturing systems. The specification language uses programming statements and commands, similar to well known manufacturing terminology, to describe and specify the system under study in the form of a model data file. Typical examples of these statements are shown in table 2.

The MAST simulator provides a standard output summary report including statistics on system variables such as system output, equipment utilization and work-in-process.

SPAR (System Planning of Aggregate Requirements) is a special menu driven pre-processor for MAST which may be used as an aggregate system design and capacity planning tool for flexible manufacturing systems. Once a feasible system design has been identified, SPAR may be used to generate an output file which may be used directly as the input to the MAST simulator for further experimentation and optimization.

BEAM (Background and Enhanced Animation for Mast) is a post-processor which may be used to create a screen animation of the simulated system.

Simulator	MAST	Modelmaster	Simfactory
Vendor	CMS Research Inc. 945 Bavarian Ct. Oshkosh, WI. 54901, USA	Genwest Indust. P O Box 5031 Benoni, 1502 South Africa	C.A.C.I. 334 N Torrey Pines Ct.,La Jolla CA., 92037, USA
Estimated price	$6500 (MAST/SPAR/BEAM)	R12000	$27500
Main application area	Manufac.Systems FMS	Manufac.Systems Job shop	Manufac.Systems Matl.Handling
Special hardware	None	None	EGA Graphics Co-processor
Animation capability	Yes (CGA)(BEAM post-processor)	Yes (CGA) (post-processor)	Yes (EGA) (real time)
Special pre-processor	Yes (SPAR)	No	No
Graphical input	No	Yes	Yes
Model management utilities	No	Yes	Yes
Model development approach	Specification language	Menu driven (question and answer approach)	Menu driven (fill-in-the-blanks approach)
Interactive capabilities	No	No	Yes (to some extent)
Trace facilities	Yes	No	Yes
Graphical output	Yes	Yes	No
Installed at University of Pretoria	Yes	Yes (Demonstration version)	Yes

Table 1 Characteristics of three manufacturing simulators

CONT,49,1,0.1,0.1,12345*	{Simulation run control}
PART,1,100,5,1,1,2,10*	{Specification of part characteristics}
ROUT,1,1,1,10*	{Specification of part routing}
STAT,1,1,1,0,1,2,3,1,1*	{Specification of work station characteristics}
TRAC,1,1,(5)2,10.*	{Specification of materials handling layout}
CART,1,2,1,20,2*	{Specification of materials handling equipment}

Table 2 Typical MAST statements

The Modelmaster simulator [17]

The Modelmaster simulator is primarily intended for the simulation modelling of job shop type of manufacturing systems and consists mainly of three different modules :

* **Layout :** Defines the simulation model by creating a factory layout with a graphics editor and provides information regarding the system parameter values through a question and answer approach.

* **Simulator :** Discrete event simulation of the model defined in the Layout phase. The simulation output data is saved in an animation file for use by the post-processor animator.

* **Animator :** Reads the animation file and performs the animation.

Using the Modelmaster simulator does not require any knowledge of a programming or simulation language and no program, in the normal sense of the word, is created. The simulator provides a standard output summary report including statistics on transporter utilization, machine cell utilization, queue statistics and system output. The animation uses different colours to distinguish between different work station states (idle, busy, blocked), and it is also possible to set the speed of the animation.

The Simfactory simulator [17]

Simfactory uses a highly professional and dedicated menu and "fill-in-the-blanks" interface to create a model. Absolutely no knowledge of a specific programming or simulation language is necessary.

A graphics editor is used to create a factory layout, define transporter paths, indicate pickup points and determine relations between queues and work stations. The length of a transporter path is determined by the length of a defined transporter path on the screen using the graphics editor.

Using the various menus and "fill-in-the-blanks" screens it is possible to define :

* Queues (maximum length, type etc),
* work station characteristics,
* process plans (routings and process times for a specific part),
* transporters (speed, type),
* station and transporter reliability,
* bill of materials,
* master production schedules, and
* reports needed.

During the simulation/animation it is possible to interrupt the simulation and inspect the system status and variables (snapshots). The animation does not show material flow, but only transporter movement and station/queue/transporter status using different colours.

Advantages and disadvantages of manufacturing simulators

At present, at least as far as the use of simulation modelling in the general manufacturing industry is concerned, the primary group of potential users of the simulation approach (process designers, engineers and manufacturing system managers) often simply do not have the necessary expertise, experience or knowledge to take full advantage of the power and benefits of the methodology [9]. The availability of powerful, high level and user-friendly manufacturing simulators may make a significant contribution to solving this problem by placing the simulation technique within the reach of the manufacturing system specialist which may not necessarily be a simulation expert.

However, if a high level manufacturing simulator is used by a person which may have no knowledge or perception of the basic underlying theory and concepts, a real danger exists of building a completely invalid model and using the model as a basis for totally incorrect decisions. Furthermore, using high level and possibly dedicated manufacturing simulators may imply a significant loss in modelling flexibility and general applicability which is one of the most important advantages of the simulation approach.

Simfactory is probably the most sophisticated and powerful, MAST the most flexible and Modelmaster the easiest to use of the presently available manufacturing simulators which have been discussed in this paper.

FACSIM : A MANUFACTURING SIMULATION PROGRAM GENERATOR [14]

The concept of a simulation program generator is not new and may be defined as follows [3] :

> "A simulation generator is an interactive software tool that translates the logic of a model described in a relatively general symbolism into the code of a simulation language and so enables a computer to mimic model behaviour".

A manufacturing simulation program generator, based on a well known and powerful general purpose simulation language, may provide the user with most of the features and advantages of a manufacturing simulator but at the same time provide access to the capabilities of the specific general purpose simulation language and even, if necessary, the capabilities of the underlying general purpose programming language for example FORTRAN, thus enhancing the available flexibility and applicability significantly.

The general design philosophy of FACSIM

The main purpose in designing FACSIM was to create a manufacturing specification language which is capable of describing a manufacturing environment accurately but to do so with as few commands as possible. Each command of the FACSIM specification language describes a specific element of a manufacturing environment and for each such command a corresponding set of SIMAN code was designed which is capable of modelling the corresponding element of the manufacturing environment.

A FACSIM simulation program, consisting of a set of FACSIM commands which describes a specific manufacturing environment, is translated into a SIMAN program. The general purpose simulation language SIMAN was chosen for this purpose mainly because of the special manufacturing and materials handling capabilities as well as the general popularity of this simulation language.

The translation process, from FACSIM to SIMAN, is performed by a simulation program generator which was coded in PASCAL.

The FACSIM specification language

The general requirements which were specified for the FACSIM specification language may be summarized as follows :

* It should be capable of describing and modelling a general manufacturing environment as accurately as possible,

* it should be relatively easy to use,

* it should be easy to maintain, expand and interface with support software,

* it should be possible to run the software on a microcomputer, and

* it should be possible to create general and compatible SIMAN code for each FACSIM command.

At the present stage of development the FACSIM specification language contains commands capable of describing and modelling the following typical manufacturing system elements :

* **Parts :**
  Specification of parts which are to be manufactured as well as information such as the quantity required.

* **Stations :**
  A description of each station including the load/unload times and the allowable queue size.

* **Routes :**
  A description of the operation sequences and operation times for a specific part.

* **Materials handling devices :**
  A description of the materials handling equipment and capacity.

* **Pallets :**
  A description of the number and capacity of the available pallets

* **Distances :**

A matrix containing the distances between the stations.

Software design features of FACSIM

The general software design features of the FACSIM simulation program generator may be summarized in pseudo-code format as shown in figure 1.

```
MAIN
      get input file name
      go to top of input file
      WHILE not end-of-file
            read block from file
            analyze the block
            IF unknown statement,
            THEN
                  write error message and line number to screen
            ELSE
                  interpret block
                  assign variables to be used in SIMAN model
            END-IF
            go to next line
      END-WHILE
      IF no error in input file,
      THEN
            open file for output
            REPEAT
                  write part creation code into file
            UNTIL no more parts
            write routing-to-first-station code into file
            REPEAT
                  write station code into file
                  write routing code into file
            UNTIL no more stations
            write last dummy station code into file
      ELSE
            write error message to screen
      END-IF
END-MAIN
```

Figure 1 Pseudo-code for FACSIM simulation program generator

FURTHER DEVELOPMENT OF FACSIM

The availability of manufacturing simulators and simulation program generators may make a significant and worthwhile contribution to the ease with which simulation modelling may be applied to the analysis and design of manufacturing systems and it may make this powerful technique available to a very broad range of potential users.

However, as already mentioned, when a simulator or simulation generator is used by a user which is relatively inexperienced in the theory of simulation modelling a very real danger exists of building and using a model for decision making purposes which is not a valid representation of the real world system.

Furthermore, the design and analysis of simulation experiments as well as the analysis and interpretation of simulation model output is a complex task necessitating in depth knowledge of topics such as stochastic stability and statistical inference. In order for FACSIM to be used effectively a need is perceived for significant additional user support features.

Since simulation studies are objective or goal driven, an approach which seems to promise worthwhile contributions to the development of such user support features is the effective use and selective application of some of the concepts of expert/knowledge base systems. Significant research in this area has been reported recently [1,3,5,10,11,12,13,15] while the simulators discussed in this paper do exhibit in some small way attempts to provide the user with some intelligent support. Furthermore, a noteworthy example in this regard is provided by a commercially available product known as CAPS (Computer Aided Programming of Simulations) which serves as an intelligent front-end processor for the general purpose simulation language ECSL (Extended Control and Simulation Language) [17]. CAPS guides the user through the simulation model development stage by way of a question and answer approach after which it generates the appropriate ECSL computer code ready for execution.

Figure 2 shows the possible components and interrelationships of a conceptual expert manufacturing simulation system, based on the SIMAN simulation language, which may be used as a guide line for the further development of FACSIM [1,3,10,11,13].

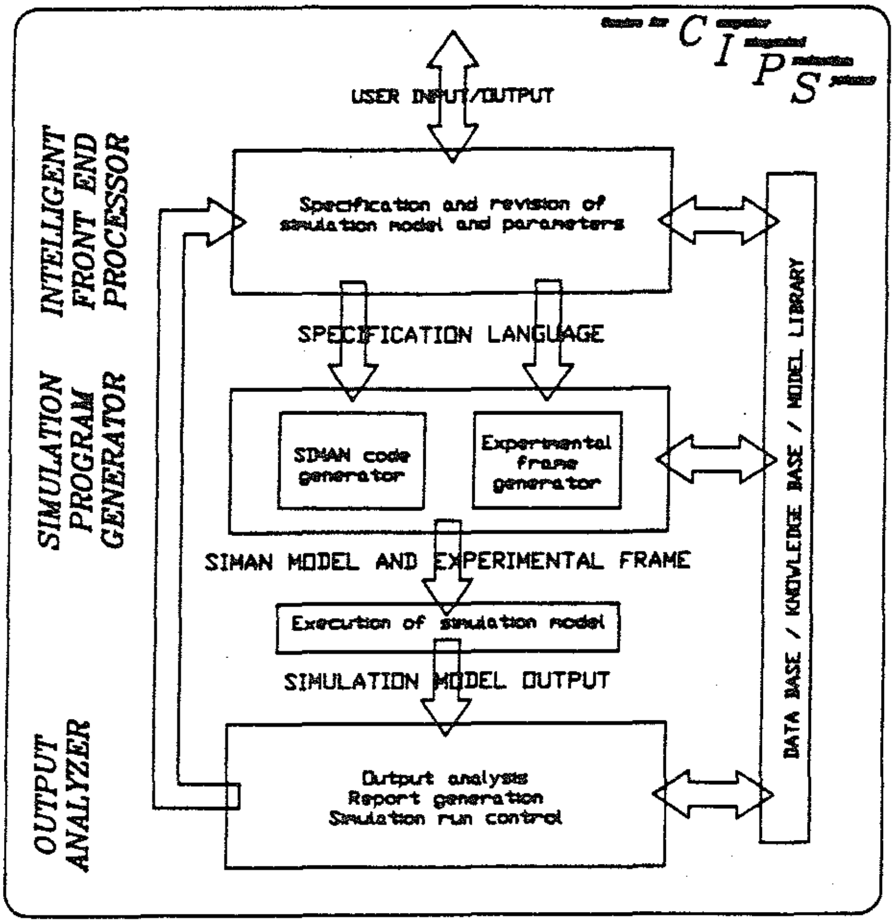

Figure 2 Conceptual expert manufacturing simulation system

CONCLUSIONS

Simulation modelling may provide a solution to the present need in the manufacturing industry for a powerful systems analysis tool. Simulators and simulation program generators may make it easier to use simulation modelling but additional support software, using the concepts of expert/knowledge base systems, should be developed.

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