INTRODUCTION TO SIMAN IV

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ABSTRACT

The SIMAN IV environment integrates the model building, running, animation and data analysis. This paper discusses the SIMAN IV simulation environment and the concepts and methods for simulating manufacturing systems using the SIMAN IV simulation language.

1 OVERVIEW OF SIMAN IV

SIMAN IV is a general purpose SIMulation ANalysis program for modeling in any of three distinct orientations. For discrete change systems, either a *process* or *event* orientation can be used to describe the model. *Continuous* change systems are modeled with algebraic, difference, or differential equations. A combination of these orientations can be used to model combined discrete-continuous models. The remainder of this paper discusses only the process orientation.

The SIMAN IV modeling framework is based on the systems theoretic concepts developed by Zeigler (1976), which stress the distinction between the system model and the experimental frame. The system model defines the static and dynamic characteristics of the system such as machines, storage points, work pieces, etc., and their interrelationships. The experimental frame defines the experimental conditions under which the model is run. This includes such elements as machine capacities and types of statistics to be recorded. Since the experimental conditions are specified external to the model description, they may easily be changed without affecting the basic model definition. Many different "what-if" questions can be answered merely by changing the experiment.

Some important SIMAN IV features include:

1. Special-purpose constructs to simplify and enhance the modeling of manufacturing systems.

2. Constructs which make it easy to model material handling devices such as AGVs and conveyors.

3. Blocks to allow input-output in the model without user-code. These support formatted, unformatted, sequential, direct-access, and spreadsheet files, providing an interface to many products and databases.

4. An interactive debugger which allows you to monitor and control the execution of the simulation. This provides a powerful tool for tracing and controlling model operation and isolating logical errors.

5. The SIMAN IV Environment which is a menu-driven tool that integrates the function of building and running the model and animation, and analyzing both input and output data.

6. Transparent use of the CINEMA IV system to generate real-time, high-resolution color animations of the system dynamics. This provides a powerful tool for both understanding and explaining the dynamics of a system.

7. Complete compatibility across mainframe, workstation, and microcomputers. Models can be moved between computer systems without modification.

2 SIMAN IV ENVIRONMENT

The following sections will review the graphical interfaces to SIMAN IV.

2.1 Model Preparation

BLOCKS and ELEMENTS are menu-driven, "fill-in-the-form" editors used to build syntactically correct SIMAN IV model and experiment files.

A block diagram model can be defined in either of two equivalent forms referred to as the diagram model and the statement model. The diagram model is a graphic representation of the system using the basic block symbols. These diagrams are linear flowcharts that depict the movement of entities through the system. The statement model is a more "programming-like" representation of the model. Either form can be generated from the other.

BLOCKS allows you to build SIMAN IV models in a graphical, block diagram format. Block diagrams are displayed in model windows on the graphics screen. The experiment frame can be created concurrently using ELEMENTS. Users who prefer to use their own text editor for model and experiment preparation may do so from within the environment while retaining its other benefits.

2.2 Input Data Analysis

The SIMAN IV Input Processor is a graphical, menu-driven program that assists the analyst in determining the best probability distribution for given sets of data, providing the appropriate expression to use in the SIMAN IV model. It fits a specific distribution to the data, allowing the analyst to compare one distribution with another. The analyst can also display the effects of changing parameters within a given distribution.

2.3 Output Data Analysis

The SIMAN IV Output Processor is a graphical, menu-driven program to help analyze data generated from simulations.

SIMAN IV generates output files that can be used to generate statistical and graphical measures of performance such as confidence intervals, correlograms, histograms, etc. One output file can be analyzed in many different ways without re-executing the simulation program. An analysis can be based on multiple runs of a model or used to compare the response of two or more systems.

2.4 Animation

CINEMA IV is a menu-driven package used to create graphical representations of SIMAN IV simulation models. When the SIMAN IV model and the CINEMA IV layout are brought together, the user is able to view a real-time animation of the simulation model with jobs or customers moving through the system. Cinema builds an animation *without any programming effort*. An animation can present information in an interesting and understandable format, point out system flaws and problems, describe the system to unfamiliar audiences, and aid in validating and verifying the simulation model.

3 GENERAL-PURPOSE MODELING FEATURES

Models are constructed as block diagrams which depict the flow of entities through the system. The block

diagram symbol shapes indicate their function. The sequencing of blocks is depicted by arrows which control the flow of entities from block to block through the entire diagram.

The entities are used to represent workpieces, information, people, etc., that flow through the real system. Each entity may be individualized by assigning attributes to describe or characterize it. For example, an entity representing a workpiece might have attributes named DueDate and ProcessingTime corresponding to due date and processing time for the workpiece. As the entities flow from block to block, they may be delayed, disposed, combined with other entities, etc., as determined by the function of each block.

Each block has operands that control its functions. For example, the CREATE block has operands which prescribe the time between batch arrivals, the first arrival time, the number of entities per batch, and the maximum number of batches to create.

Blocks may optionally be assigned a block label and one or more block modifiers. A block label is used for branching or referencing from other blocks. Block modifiers can modify or extend the standard function to be performed by the block.

To illustrate the general purpose modeling approach of SIMAN IV, consider the simple manufacturing system in which workpieces arrive, are processed in order on a single machine, and then depart the system (Figure 1).
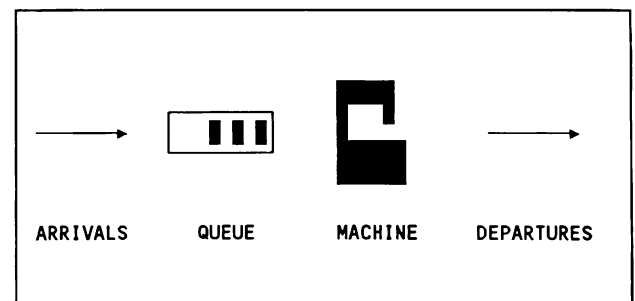

Figure 1: Schematic of a Simple System

The block diagram model for this example is shown in Figure 2. The workpieces enter the system at the CREATE block. The operands for this block specify that the workpieces enter in batches of 10 and that the interarrival time between batches is exponentially distributed with a mean of 20. The workpieces continue to the QUEUE block named Buffer where they wait in turn to seize a unit of the resource Machine. Once a workpiece seizes the Machine, it enters the DELAY block where it is delayed by the processing time which is specified as a sample from a uniform distribution between 1 and 2. Following this, the workpiece

releases the resource Machine, which allows it to be re-allocated to workpieces waiting in the QUEUE block. The symbol attached to the bottom of the RELEASE block is called the DISPOSE modifier and models the departure of the workpiece from the system.

```
┌─────────────────────────────┐
│         CREATE,10           │
├─────────────────────────────┤
│         EXPO(20.0)          │
└─────────────────────────────┘
              │
              ▼
      ╭───────────────────╮
      │   QUEUE,BUFFER     │──────▶
      ╰───────────────────╯
          ╱
┌─────────────────────────────┐
│          SEIZE              │
├─────────────────────────────┤
│         MACHINE             │
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│          DELAY              │
├─────────────────────────────┤
│        UNIF(1,2)            │
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│         RELEASE             │
├─────────────────────────────┤
│         MACHINE             │
└─────────────────────────────┘
```
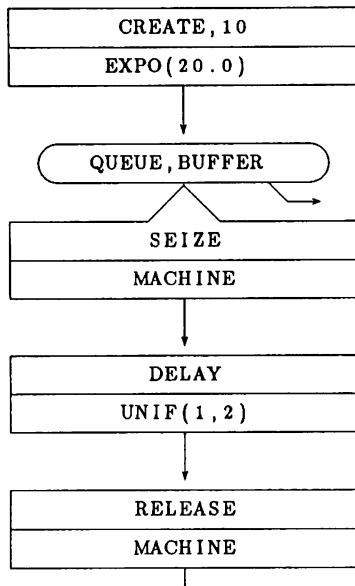
Figure 2: Block Diagram for Simple System

An example experiment frame for this model is shown in Figure 3. It specifies the conditions associated with the model and includes the definition and capacity of the resources employed, a specification of the number and length of each simulation replication, etc.

```
Begin;
Project,Simple System,Analyst;
Queues: Buffer;
Resources: Machine, 1;
Replicate, 1, 0, 480;
End;
```

Figure 3 : Experiment for Simple System

4 MANUFACTURING FEATURES

In this section, we will describe the features included in SIMAN IV for modeling the characteristics of manufacturing systems.

4.1   Modeling Workstations

Large manufacturing systems typically consist of a number of different workcenters or cells. A natural way to model such systems is to decompose the large system into its workcenters, modeling each workcenter separately, and then combine the workcenter models into an overall system model. This can be done within SIMAN IV by employing the STATION block which defines the beginning of a station submodel. An entity is entered into the station submodel by sending the entity to the STATION block using a transfer block. A transfer block, such as the CONVEY or TRANSPORT block, is used to represent entity movements between station submodels.

Each station submodel is referenced by a station name (e.g. Inspection) and a station number which corresponds to a physical location within the system. The station name or number, which can be used interchangeably, is an operand of both the STATION block and a transfer block.

When an entity enters a STATION block, the entity's station attribute, M, is set to the station number. The entity carries this special attribute with it as it proceeds through the sequence of blocks which comprises the station submodel. The entity remains within the station submodel until it is disposed, or until it is sent to a new station submodel via a transfer block. The block sequence within a station submodel defines the processes through which the entities flow.

To illustrate the concept of a workcenter submodel, consider the block diagram submodel shown in Figure 4. This block diagram contains the frequently occurring sequence QUEUE-SEIZE-DELAY-RELEASE which can be used to model both a single-server and a multi-server queueing system, depending on the capacity for the resource that is specified in the experimental frame.

The workpieces arriving to this submodel enter the STATION block named Lathes, proceed through the QUEUE-SEIZE-DELAY-RELEASE blocks and then enter the ROUTE block. The ROUTE block is a transfer block which routes the workpieces to their next workcenter.

The block sequence in this example is particularly simple and employs only a small subset of the features of SIMAN IV. Once the analyst becomes familiar with the wide range of block functions included in SIMAN IV, complex workcenters can be modeled with similar ease.
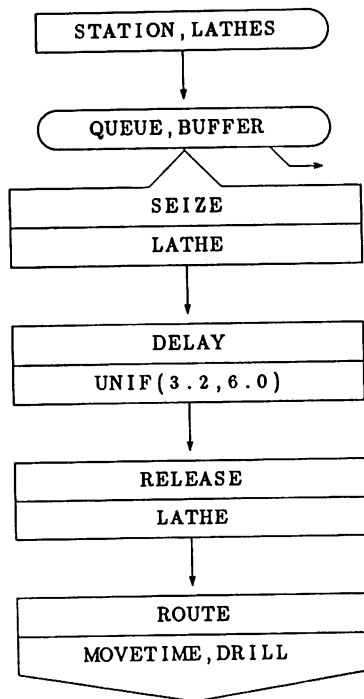
```
(  STATION,LATHES  )
         |
(   QUEUE,BUFFER   )
        /\
[      SEIZE       ]
[      LATHE       ]
         |
[      DELAY       ]
[  UNIF(3.2,6.0)   ]
         |
[     RELEASE      ]
[      LATHE       ]
         |
[      ROUTE       ]
[ MOVETIME,DRILL   ]
```

Figure 4: Block Diagram of a Workcenter

4.2 Macro Submodels

One particularly useful feature for modeling workcenters in SIMAN IV is the macro submodel. This powerful feature permits the development of a single macro submodel to represent two or more similar yet distinct workcenters. For example, a typical jobshop consists of several different workcenters (lathes, drills, etc.) that are functionally equivalent and differ only in their number and type of machines, buffer sizes, etc. We can model this jobshop by constructing a single macro sub-model which represents the process encountered by a job at a general jobshop workcenter. This single macro submodel can then be used to model a jobshop of arbitrary size.

The beginning of a macro submodel is defined by a STATION block. The range of stations represented by the macro submodel is specified as the operand of the block. An entity is entered into the macro submodel by sending it to the STATION block using a transfer block. All entities sent to a station in the specified range of the STATION block are processed as arrivals to the block. Upon entering the STATION block, the station attribute M of the entity is set by SIMAN IV to the station to which the entity was sent.

When a macro submodel is employed, the station attribute is typically incorporated in the operands of one

or more of the blocks that follow the STATION block. In this way, the operation of the macro submodel can depend upon the station of the entity. For example, the station attribute could be used to specify a queue number or the entity could be branched within the submodel based on its current station.

4.3 Process Plans

As illustrated in the previous example, a workpiece is sent to its next workcenter using a transfer block. However, the transfer block must have some way to determine which workcenter is next in sequence for a particular workpiece. In addition, it may be necessary to update one or more attributes of the workpiece to correspond to the processing parameters at that workcenter.

The workcenter visitation sequence and corresponding attribute update values are specified in SIMAN IV using the SEQUENCES element.

The SEQUENCE element permits defining steps in a process plan as well as defining the data associated to the plan such as setup times, special tool requirements, etc. In addition, a step of the process plan could be repeated or skipped, or an alternate process plan could be followed.

4.4 Resource Schedules

The workcenters within a manufacturing system often operate according to different work schedules as a result of their differing loads. Within SIMAN IV, this can easily be modeled through the use of the SCHEDULES element. This element is used to define a work schedule by specifying a resource capacity over time. A resource capacity within the model can then be directed to follow a given work schedule. For example, the resources in workcenter 1 might be directed to follow schedule number 1 and the resources in workcenter number 2 might be directed to follow schedule number 2.

The SCHEDULES element shown in Figure 5 defines two different work schedules:

```
SCHEDULES:
1, 1*8, 0*16:
2, 1*EXPO(5.5), 0*UNIF(.5,1);
```

Figure 5: SCHEDULES Element

In schedule number 1, the capacity is 1 for 8 time units, then 0 for 16 time units, and then this cycle

repeats. In schedule number 2, the capacity is 1 for a duration that is sampled from an exponential distribution, and then 0 for a duration that is sampled from a uniform distribution, and then this cycle repeats. Note that schedules can be used to represent breakdowns and repair activity for a resource such as a machine.

4.5   Modeling Material Handling Systems

Within a manufacturing system, the movement of entities between workcenters is accomplished by the material handling system. This is an extremely critical function in most manufacturing systems that can easily account for a significant percent of the production activity.

The categorization of material handling equipment into the two basic movement functions of transport and convey provides the basis for modeling these devices in SIMAN IV. The transport function corresponds to the intermittent movement of items, one load at a time, along a fixed or varied path. The term load as applied here could denote a box, a roll of material, or a pallet containing a number of items grouped together. The convey function corresponds to the continuous movement of items along a fixed path. Special blocks and elements are included in SIMAN IV that allow both of these movement functions to be modeled in a straight-forward manner.

The blocks that are used to model material handling systems employ the concept of a station submodel as discussed earlier. All movements are made relative to station names assigned to each station submodel. The travel time for entities between stations is based on the speed of the material handling device and the spatial relationship of the origin and destination stations relative to the device. Both of these are specified by the modeler in the experimental frame.

4.5.1   Transporters

The generic term *transporter* is used in SIMAN IV to denote a general class of movable devices that may be allocated to entities. Examples of devices which might be modeled as transporters are carts, cranes, and mechanical manipulators.

There are two different types of transporters in SIMAN IV. The first, standard transporters, are unconstrained in their movement between stations. These are useful in modeling situations where transporter traffic congestion is minimal. The second, called guided transporters, are used to model situations where the transporters are constrained to moving over a defined network consisting of links and intersections. Guided transporters are particularly useful for modeling auto-matic guided vehicles (AGVs) and automated storage and retrieval systems (AS/RS).

The characteristics of each transporter type are specified in the experimental frame and include the name, capacity, system map, and the initial station position and operational status of each of the transporter units for that type. The capacity is the number of independent movable units of that transporter type. The system map is a cross-reference to a definition of the feasible travel paths and associated travel distances between pairs of stations which each transporter unit of that type may visit. In the case of guided transporters, the system map includes a description of the network of links and intersections.

Transporter units are allocated to entities at a RE-QUEST block, after which the entity can be transported from one station to the next using the TRANSPORT block. The duration of the transport is automatically computed by SIMAN IV based on the distance to the station and the speed of the transporter unit. For guided transporters, the travel time may be further influenced by other traffic in the system. At the end of the transport duration, the entity enters the STATION block of the destination station submodel.

4.5.2   Conveyors

The generic term *conveyor* is used in SIMAN IV to denote a class of devices which consist of positioned cells linked together that move in unison. Each cell represents a location on the device and can be either empty or occupied. Entities that access the conveyor must wait at the entering station until the specified number of consecutive empty cells are located at the station. The entity then enters the conveyor and the status of the cells are changed from empty to occupied. The entity remains in the cells until the conveyor is exited at the entity's destination station.

Each conveyor in SIMAN IV can be defined to be either accumulating or non-accumulating. In an accumulating conveyor, an entity that is stopped on the conveyor forms a blockage point for other entities that continue to move on the conveyor. Entities arriving to the blockage point accumulate behind the blockage. In a non-accumulating conveyor, an entity that stops on the conveyor forces the entire conveyor to stop. As a result, there is no accumulation of entities.

Each conveyor device moves along a fixed path defined by one or more segments. A segment is a section of a conveyor path that connects two station submodels. Segments can be connected to form either open- or closed-loop conveyor paths. A closed-loop path is one in which an item on the conveyor can return to a station by continuing on the device. An open-loop path is one

that is not closed. The segments defining a conveyor path are specified in the experimental frame.

4.6 Modeling Shop Floor Control

A rapidly growing application of simulation is finite capacity scheduling. Simulation is a powerful tool for scheduling. Although there are simulation-based packages targeted specifically at scheduling, a general-purpose simulation language has several advantages:

a) Models developed and verified during system design can be reused during later analysis and control.
b) The same simulation language can be used through all modeling phases.
c) It is easy to accurately model complex systems.
d) You have the benefit of powerful animations to aid in user training and acceptance.

SIMAN IV contains many constructs that aid in model initialization, database access, report generation, defining Process Plans, JIT, and advanced manufacturing constructs.

Systems Modeling is constantly improving the use of SIMAN IV for Shop Floor Control and is currently developing a product specifically oriented toward scheduling applications.

5 SUMMARY

Since its introduction, SIMAN has been used in a wide range of applications by numerous companies throughout the world. Although many of the applications have been simulations of manufacturing systems, SIMAN has also been applied to general system simulation including health care, computer, and retail systems. SIMAN IV is continually enhanced to retain its position as the state-of-the-art in simulation.

In this paper, we have given only a brief overview of the modeling features of SIMAN IV with an attempt to highlight those features which are particularly relevant to manufacturing systems. Only a small subset of the block functions were discussed, and no attempt was made to describe the enhanced general-purpose features included in the language.

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