INTRODUCTION TO SLAM II AND SLAMSYSTEM

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ABSTRACT

SLAM II was the first simulation language which allowed a modeler to formulate a system description using process, event, or continuous world views or any combination of the three. Since its initial release in 1981, SLAM II has undergone continual development and application. SLAMSYSTEM, introduced in 1988, provides SLAM II with an integrated simulation system for advanced personal computers. SLAMSYSTEM supports the entire simulation process, from model building to results presentation and documentation.

1. INTRODUCTION

SLAM II, the Simulation Language for Alternative Modeling, was the first simulation language which allowed a modeler to formulate a system description using any of three approaches (world views) or any combination of the three. SLAM II integrates the process-oriented world view and the discrete-event/continuous world views in order to free the modeler to select the approach which best represents his or her system or the approach that is most comfortable. This integrated framework allows the SLAM II user to take advantage of the simplicity of the process-oriented (network) approach and to extend a model with discrete event constructs should the network approach become too restrictive. Continuous variables may be used in conjunction with a network or discrete event model whenever this is the most convenient way to represent system elements. The ability to construct combined network-event-continuous models with interactions between each orientation makes SLAM II an extremely flexible tool for simulation.

Since its introduction, SLAM II has continued to evolve as a result of extensive application. Experience with thousands of models has demonstrated the flexibility of the language, but has also pointed out the ways in which SLAM II could be extended for greater ease of use.

In addition to enhancements to the modeling language itself, the following software has been developed for use with SLAM II:

- A Material Handling Extension (MHEX) provides detailed modeling of regular and special resources (cranes, storage areas, automatic guided vehicles, and guidepaths).

- The SLAM II Interactive Execution Environment (IEE) allows the interruption of a simulation in order to examine system status, reassign variable values, step through events, or call SLAM II support routines for debugging or gaming.

- TESS (The Extended Simulation System) provides complete simulation project support, including functions for fitting data to probability distributions, database management for simulation output data and facilities for graphically building models and analyzing, graphing, and animating model results on workstations and multi-user systems.

- SLAMSYSTEM includes SLAM II in an integrated simulation system for personal computers.

This tutorial will introduce both the basic modeling techniques used in SLAM II and the project support features of SLAMSYSTEM. It omits any discussion of the specialized material handling features (Sale, 1987), continuous modeling, or interactive debugging.

2. NETWORK MODELING

A simulation model normally begins with a network, or flow diagram, which graphically portrays the flow of entities (people, parts, or information, for example) through the system. A SLAM II network is made up of "nodes" at which processing is performed. SLAM II nodes, shown in Figure 1, provide for such functions as entering or

exiting the system, seizing or freeing a resource, changing variable values, collecting statistics, and starting or stopping entity flow based on system conditions. Nodes are connected by branches, called "activities", which define the routing of the entities through the system. Routing may be deterministic, probabilistic, or based on system variables. Time delays on activities may represent processing times, travel times, or waiting times. Entities which proceed from node to node over activities may have unique characteristics, or "attributes", which control their processing. Entities may reside in "files", or ordered lists of entities which are waiting for some change in system status. The graphical framework for representing a network model simplifies model development and communication.

The process of building a SLAM II network model consists of choosing the symbols which can represent system processes, combining them in a diagram which represents the entity flow, and parameterizing the symbols with model-specific data. A single-server queueing model (representing, for example, a workstation) is shown in Figure 2. The network begins with a CREATE node which generates the first job arrival at simulated time 0.0 and continues to generate arrivals at a rate drawn from an exponential distribution. A QUEUE node is used to delay arrivals until the station is available. The station, whose processing time is sampled from a normal distribution, is represented by the ACTIVITY, or branch, following the QUEUE. Upon completion of the activity, a COLCT node records the interval between departure time and the job's arrival time, which was stored in attribute 1. The graphic modeling approach is both quick to use and an effective way to communicate the structure of a model. The output from this model would automatically report statistics on job waiting time, queue length, station utilization, time in system and throughput.
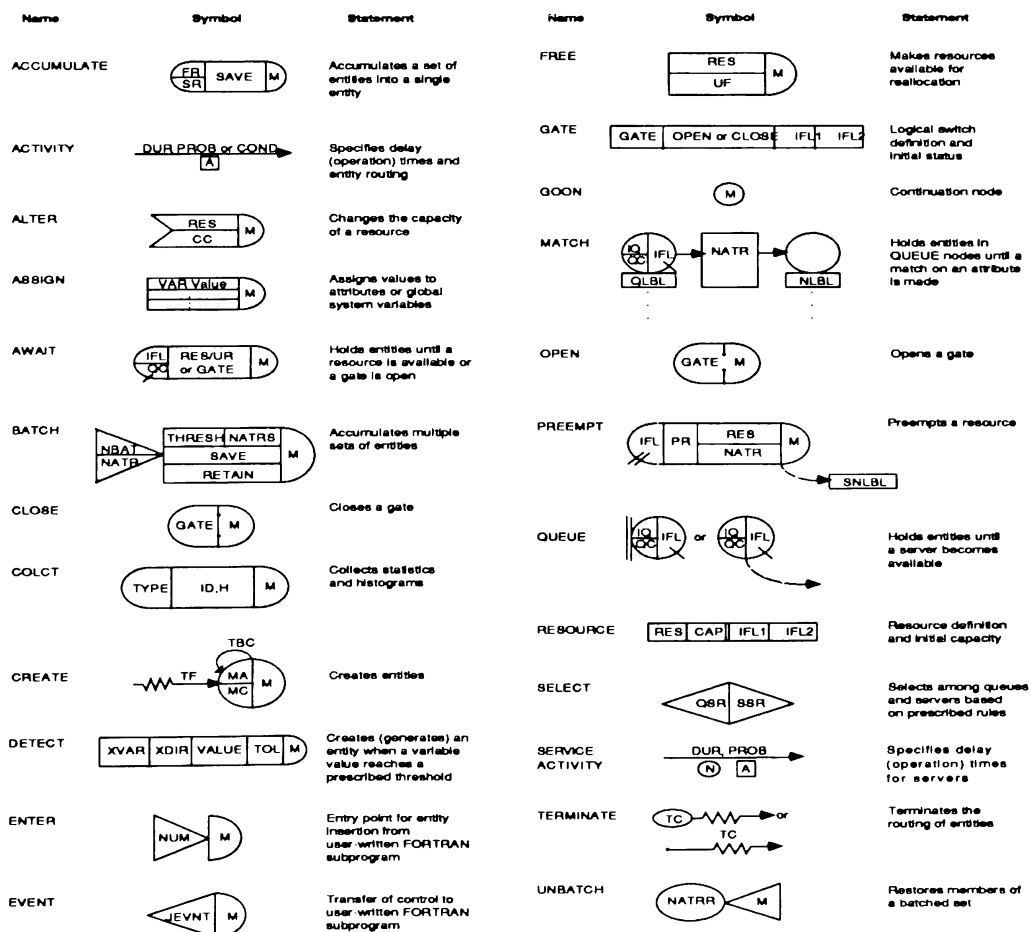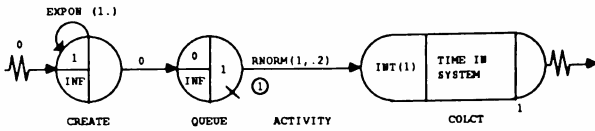

Figure 1: SLAM II Network Symbols

Figure 2: A Single-Server Queuing Example

A network may be built interactively and graphically using TESS or SLAMSYSTEM, or by translating the diagram into a set of input statements. In statement form a SLAM II model is portable to a wide variety of computer systems. In addition to the network, this model would include a set of control statements defining experimental conditions such as run length, statistics clearing, and other parameters.

3. USER-WRITTEN INSERTS

In case a network model cannot capture enough detail of the system under study, SLAM II provides several interfaces to user-written inserts. One such interface is the EVENT node, a "do-it-yourself" node which simply invokes a user-written subprogram, often used to process very complex decision logic. Over 100 functions and subroutines may be accessed from an EVENT node, to obtain information on system status or to change that status in a variety of ways. Other interfaces to user-written logic provide for complicated variable calculations, sophisticated resource allocation schemes, specialized initial conditions, and tailored output reports. User inserts are normally written in FORTRAN, although they may be written in C or in any other language that can be linked to FORTRAN.

4. SLAMSYSTEM OVERVIEW

SLAMSYSTEM integrates software supporting the range of tasks performed in a simulation project, using the Microsoft Windows interface. All features are accessible through pull-down menus and dialog boxes, and are selected from the SLAMSYSTEM Executive Window, shown in Figure 3.

A SLAMSYSTEM project consists of one or more scenarios, each of which represents a particular system alternative. A scenario is comprised of components such as a network and control, user inserts and user data, animation facilities and scripts, notes for model documentation, and model output. The Current Scenario Box in the SLAMSYSTEM Executive Window shows the components associated with the scenario presently being analyzed.
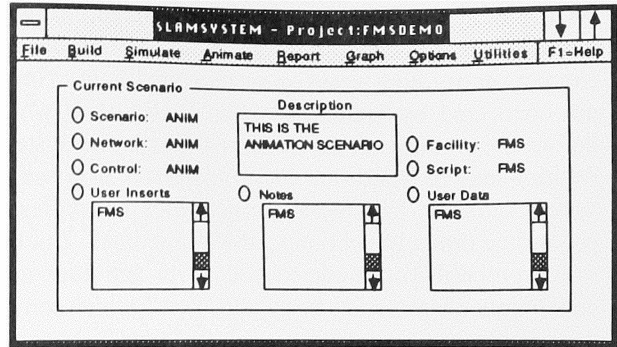

Figure 3: SLAMSYSTEM Executive Window

SLAMSYSTEM's project maintainer removes the burden of remembering the procedure necessary to perform the tasks of simulation, animation, and output review. Each time the modeler requests one of these functions, the project maintainer examines the components of the current scenario to determine if any of them have been modified, indicates whether tasks such as model translation and executable creation should be performed to reflect the changes, and allows the user to specify whether these tasks should be done prior to performing the requested function.

Since SLAMSYSTEM is a Windows application, multiple tasks may be performed in parallel while simulations are executed in the background. The simulation modeler can switch between tasks by using a mouse to click in the appropriate window.

5. BUILDING MODELS WITH SLAMSYSTEM

SLAMSYSTEM may be used to build SLAM II models with the assistance of the graphical network builder (Figure 4) and the forms-oriented control builder. These builders use the mouse and a forms-based approach to aid the modeler in the entry of the system description. They remove the need to remember syntax and field definitions, and allow the modeler to concentrate on constructing models.

Network symbols are selected from a graphical palette and located with the mouse. The symbol's parameter values are specified by filling out a form of information applicable to the particular symbol. On-line error checking is performed upon completion of the form so that input errors can be corrected immediately. Networks can be viewed at three levels of detail. At the highest level, more than 150 symbols can be seen at once. The Windows "Clipboard" can be used for copying a set of symbols to other positions in the network or to other networks or

applications. Symbols may be repositioned by selecting and re-locating them with a mouse. The Network Builder also facilitates model building by providing context-sensitive help, searching capabilities, and options for placing symbols at grid points, selecting symbol colors, and flowcharting models by defaulting symbol parameters.
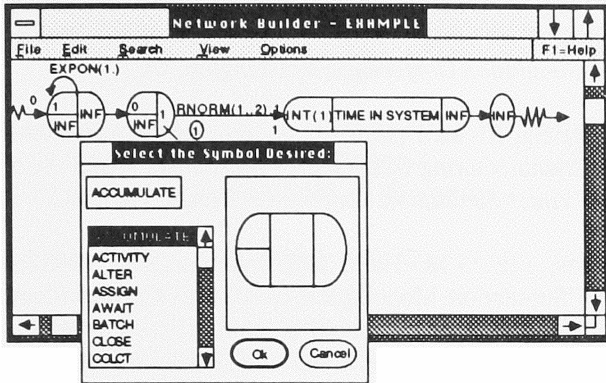

Figure 4: Graphical Network Builder

A model's control statements are entered by selecting from a palette of available statements. The parameters of each statement are defined by entering the desired values in the fields of a form specific to that type of statement. As with network symbols, most fields have default values.

Alternatively, networks and controls may be entered in SLAM II statement format with SLAMSYSTEM's textual editor. The Network Builder is capable of loading a network built textually by automatically placing symbols to create a graphical network.

6. OUTPUT ANALYSIS AND PRESENTATION

SLAMSYSTEM provides the capability for comparing simulation outputs from various scenarios both graphically and textually. A report "browser" allows alternative textual outputs to be compared side by side. Graphically, output may be viewed in the form of bar charts, histograms, pie charts, and plots. Bar charts can be used to display the value of a statistic across as many as 10 scenarios. It is possible to view multiple windows of graphical output at a single time, as shown in Figure 5. Graphical and textual information from SLAMSYSTEM graphs and reports can be exported to other Windows packages for additional analysis and for documentation.
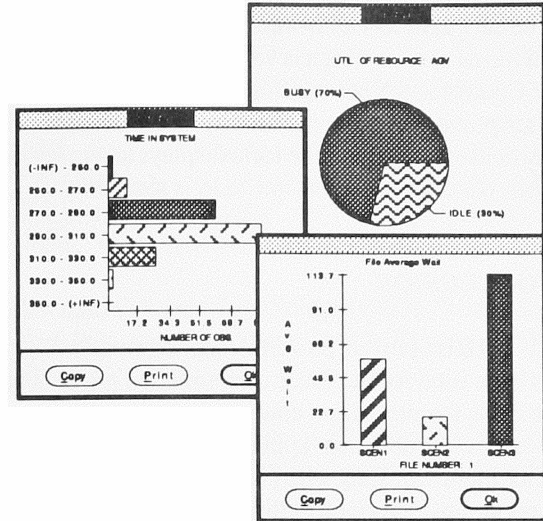

Figure 5: Multiple windows

7. ANIMATING MODELS

Animations are created with the Facility and Script Builders. The Facility Builder is used to design background screens, symbols and graphs, to define points on the screen where animation actions will occur, and to create application files which specify the background screens and graphs to be used during an animation. The Script Builder is used to specify which animation actions should occur when a particular simulation event happens. Animations can be performed either concurrently with the simulation or in a "post-process" mode. Plots, barcharts, histograms, and trend graphs may be shown along with symbol movements, color changes, numeric value displays, text placements, and stack updates. Two screens can be updated simultaneously, and up to 255 screens may be swapped into memory during an animation.

The Facility Builder allows the modeler to design background screens and symbols by drawing lines, outlines, boxes, circles, ellipses, arcs, and points using 16 standard colors, 16 hatch patterns, and 16 colored patterns. Sections of the background screens and symbols can be copied, moved, mirrored, rotated, and color swaped. Symbols may be transported back and forth between symbol tables and background screens. Facility screens can be imported from other software packages such as AutoCad.

The Script Builder allows animation rules to be entered with a forms system which is very similar to the one used in the Control and Network Builders. The parameters of each script statement are specified by filling out a form for the particular statement. The form displays all the options for each parameter, and on-line help is available.

8. CONCLUSION

SLAM II is a proven, powerful modeling methodology. It has been used for hundreds of simulation projects and as the basis for simulation courses in many colleges and universities. Published applications (see references) describe models dealing with problems in manufacturing, transportation, material handling, staffing, experimental design, communications systems, and many more.

Continuing development of SLAM II and simulation support software has culminated in TESS and SLAMSYSTEM, integrated simulation systems for workstations and personal computers. SLAM II, TESS and SLAMSYSTEM are distributed by Pritsker Corporation, which offers regularly scheduled training classes as well as applications support.

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