Proceedings of the 2000 Winter Simulation Conference
J. A. Joines, R. R. Barton, K. Kang, and P. A. Fishwick, eds.

MODELING WITH THE MICRO SAINT SIMULATION PACKAGE

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ABSTRACT

Micro Saint is a discrete-event simulation software package for building models that simulate real-life processes. With Micro Saint models, users can gain useful information about processes that might be too expensive or time-consuming to test in the real world. Some common application areas for simulation modeling include the following:

- Modeling manufacturing processes, such as production lines, to examine resource utilization, efficiency, and cost.
- Modeling transportation systems to examine issues such as scheduling and resource requirements.
- Modeling service systems to optimize procedures, staffing and other logistical considerations.
- Modeling training systems and their effectiveness over time.
- Modeling human operator performance and interaction under changing conditions.

Simulation is a cost-effective way to help show decision-makers the most cost-efficient alternatives to any problem.

1 INTRODUCTION

Discrete event simulation has been a standard technique in the analysis of manufacturing systems for years. Attention to the value of simulation in evaluating alternative strategies to reduce costs has also increased in other industries as a result of competitive pressure and rising costs. The adoption of total quality management (TQM) and process management techniques has created new challenges for managers and engineers. Simulation is now being used to evaluate and improve efficiency in a myriad of areas, including: process definition, quality measurement and control, process re-design, employee workload, safety and productivity. With decision-makers applying simulation technology to a wider variety of problems, the need for general purpose simulation tools that are capable of addressing all these needs has increased. Micro Saint, a task network based modeling tool, is recognized to be an efficient and cost-effective tool for simulating the complexities of systems within a variety of industries ranging from the government to health care. Problems being analyzed within these industries range from process control and resource utilization, to military maintenance procedures and human performance.

The purpose of this paper is to provide a basic understanding of the principles of modeling with Micro Saint and to demonstrate examples of how this tool has been used.

2 METHODOLOGY

Micro Saint was developed in 1985 specifically for modeling human performance in complex systems. One of the biggest challenges in the original development project was to provide a powerful and flexible tool that could be used by psychologists and human factors engineers, not just simulation experts or computer programmers. Since psychologists and human factors engineers have limited exposure to both simulation and computer science, a modeling approach that was entirely different from other simulation products available at the time was required. The engineers at Micro Analysis and Design, Inc. developed Micro Saint, implementing a methodology known as task network modeling. Activities are represented in a diagram as nodes and the arrows between the nodes represent the sequence in which the activities are performed. A simple task network is shown in Figure 1.

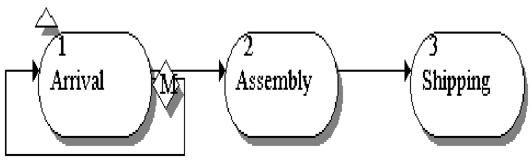

Figure 1: Sample Network Diagram

This approach allowed users to develop models using the same techniques they would use to define a flow diagram of the activity. Each activity, whether it is a human activity or a system activity, is defined using the same method. This minimizes the complexity of the user interface and eliminates the need for programming blocks specific to an application.

Over the years, the size and scope of the problems to which users wanted to apply Micro Saint increased. This integration of Micro Saint into other application areas, such as the manufacturing and service industries, greatly influenced subsequent product development and enhancements. For example, there is rarely a need for defining queues when developing models of human performance, however, in order to remain competitive in the manufacturing market, the capability to define queue parameters such as exit order was critical.

While it has continued to evolve over the years, Micro Saint's origin in human performance modeling is still evident in the terminology that is associated with the product. A Micro Saint model is composed of "networks" which may be a sequence of tasks to be performed by a human, a series of processes that define an organization, or a machine in a manufacturing plant. Networks are composed of either lower-level networks or "tasks." Although the identifier "task" has connotations of human activity, it is not restricted to such. Tasks represent the lowest level in the model and have specific parameters (timing information, conditions for execution, beginning and ending effects).

3 MODEL DEVELOPMENT

The process of building a Micro Saint model involves two separate but interrelated steps. First, the user must define the structure of the task network. This is done by selecting the appropriate tool from the tool palette and placing the object in the drawing space of the network diagram. The Micro Saint tool palette and drawing space is presented in Figure 2.

Micro Saint uses the windows standard "point and click" approach to define network objects. Using the mouse to "double-click" on an object will open it so that information specific to the object may be entered. Figure 3 is an example of the Task Description window that is opened when the user double-clicks on a task (i.e., node in the network). The following section explains the task parameters in more detail.

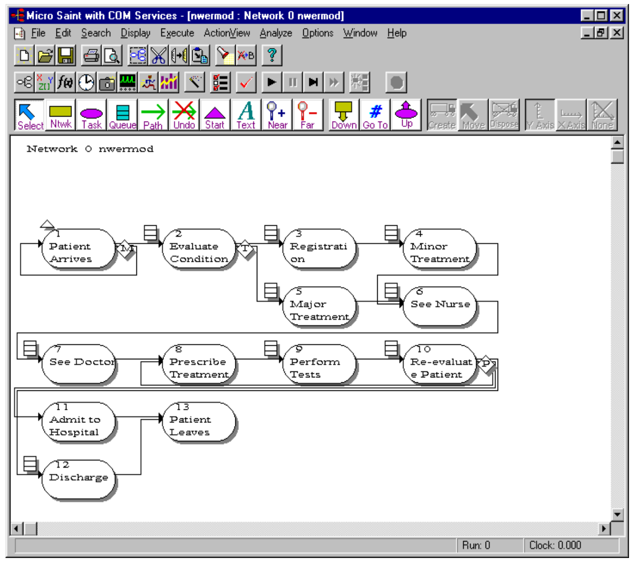

Figure 2: Micro Saint Tool Palette

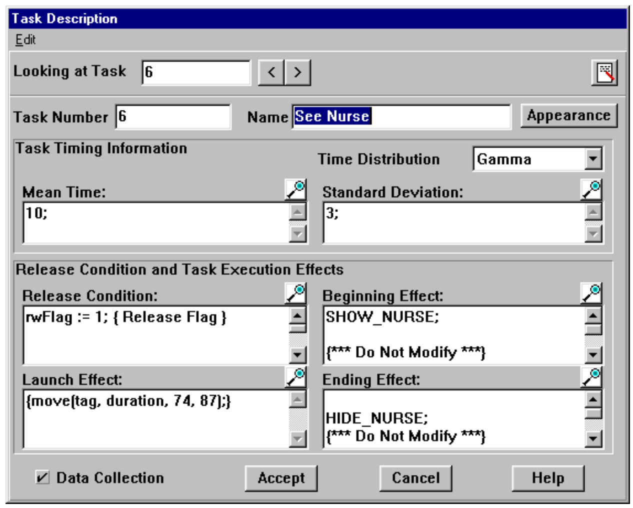

Figure 3: Task Description Window in Micro Saint

3.1 Task Timing Information

The task "mean time" is the average time that a task takes to complete once it has begun executing. For example, if the task represents a human activity such as "transfer patient to recovery room," then the mean time to execute is the average time that it takes to perform the task. If the task represents a machine in a manufacturing process, then the mean time to execute is the average processing time for the machine. In many cases the execution time is not constant, rather, the elapsed time falls within a range of values that can be represented by a time distribution. Micro Saint supports more than 21 distribution types including normal, rectangular, exponential, gamma, Weibull, Poisson and others. In addition, users may enter parameters that control the spread of the distribution.

Alternatively, the mean time may be determined by the current state of the system or by an attribute of the process itself. In human performance modeling, the mean time to perform a task may be influenced by such conditions as how long the human has been working, the skill level of the human, or the current workload. In an insurance claim processing model, the type of claim or the location of the client may determine the time it takes to process a claim.

3.2 Conditions for Execution

Often, there are situations where a task cannot begin executing until certain conditions are met. A customer cannot make a transaction at a bank, even though the queue is empty, until a bank teller is available. A task may have resource requirements or other constraints (i.e., time of day, part type) that dictate when the task may begin executing. In Micro Saint, users enter a Boolean (logical) expression in the "release condition" field to control the execution of tasks. The release condition expression may be as simple as "teller <> 0", or it may be a complicated expression where several conditions are evaluated such as, "(clock > 8 & clock < 16) & (clerk <> busy)." Entities moving through the network, such as patients, parts, or claim forms cannot be released into a task for processing until the release conditions for the task have been met.

3.3 Beginning/Ending Effects

The current state of the system may change when a task begins or ends. For example, when a machine begins processing a part it becomes "busy" and is not available to another part until it has finished. The user would define the following expressions in Micro Saint to define this condition:

Release Condition: busy == 0; This keeps an entity (e.g. part, patient, etc.) from moving into the task when the task is "busy" processing another entity.

Beginning Effect: busy := 1; This sets the busy flag to TRUE so that the next entity cannot enter the task. As long as the task is executing, the busy flag will remain equal to "1".

Ending Effect: busy := 0; When the task finishes executing, the ending effect is evaluated and the busy flag is set to 0. Now, when the release condition is evaluated, the condition will be true and the next entity can enter the task.

This relationship between the release condition and the beginning and ending effects provides a general, yet powerful mechanism for users to define complex behaviors within the system they are modeling. Users may define variables that are specific to their system and manipulate the value of the variable as needed so that they can accurately represent their system. They do not have to compromise the accuracy of their model by relying on pre-defined "blocks" within the modeling tool nor do they have to learn a complex programming language in order to obtain the level of control required.

A feature that greatly increases Micro Saint's power is a "parser" that evaluates algebraic expressions. It provides the mathematical power of computer programming languages such as Visual Basic and C, but eliminates the need for compiling the model before running it. One of the biggest advantages of the parser is that it allows users to interactively change the values of model parameters while the model is executing. For example, the user could increase the number of bank tellers available or change the execution time for a task while the model is executing to see what the overall effects on the system would be.

3.4 Task Sequencing

Task sequencing is defined by clicking and dragging with the mouse from the first task to the following task(s). When more than one following task is defined, a diamond shaped "decision icon" appears on the network diagram. Users must enter the conditions that control the branching when there is more than one following task. Micro Saint provides the following decision types to ensure that all real-world situations may be represented in the model:

Probabilistic – The following task conditions are evaluated and the next task to execute is determined by the relative probabilities of all tasks listed. Only one of the following tasks will be executed with probabilistic decisions.

Multiple – The following task conditions are evaluated and all of the tasks whose conditions evaluate to non-zero will execute.

Tactical – The following task conditions are evaluated and the next task to execute is the task whose condition evaluates to the highest value.

Variables and algebraic expressions can be used in the branching logic and the value of the variables can be changed by conditions in the model. This gives the user complete control and manipulation of the network flow. Figure 4 is an example of a tactical decision that controls the flow of patients in an emergency room model through the network based on the seriousness of their injury.

All of these features provide an environment for the model developer that is easy to learn and easy to use. Once the basic concepts are understood, any system or process can be modeled using Micro Saint. In addition, users can build models at any level of complexity. Some applications may require a very low-level, detailed definition, while with others a high-level definition is sufficient.

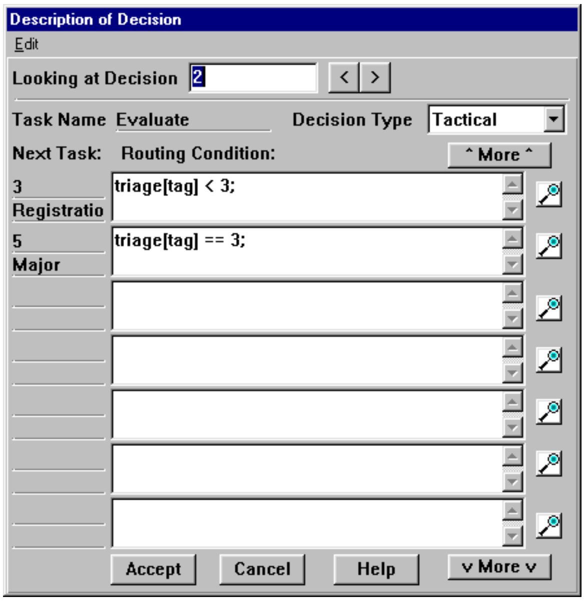

Figure 4: Micro Saint Tactical Decision

4 OPTIMIZATION

Micro Saint includes OptQuest, a model optimization function. OptQuest allows users to automatically search for optimal solutions to complex systems. The concept of optimizing solutions is very simple and very useful. Most simulation models have constrained resources controlled by the user that affect system performance. These resources represent design variables that are critical to decision makers. Typical questions related to resources are:

How many machines of each kind should be brought in order to maximize the throughput without exceeding the budget?

How many tellers and supervisors should be employed in a bank in order to maximize utilization while minimizing expected waiting time for the customer?

What delivery frequency and batch size should be used in a just-in-time system in order to minimize inventory and production costs?

OptQuest allows for the creation of intelligent search procedures capable of finding optimal or near-optimal solutions to complex problems while only evaluating a small fraction of the possible alternatives. OptQuest allows you to find high performance parameter settings efficiently for your most complex simulation model.

5 ANALYSIS AND RESULTS

People build models to provide insight to, or answer specific questions about, a system or process. Some information can be gained by watching the Micro Saint model run. Micro Saint's symbolic animation capability provides an animated view of the network diagram as the model is running. Users can watch as entities flow through the network or wait in queues before being processed. This type of animation is particularly useful in debugging the model. An example of an animated network is shown in Figure 5.

Micro Saint also provides an iconic animation capability called ActionView (see Figure 6) that allows users to build a realistic "picture" of their model.

Sometimes it is sufficient to save the state of the system at the end of the run. However, in order to gain insight into the dynamic aspects of the system, users can "take snapshots" of the model variables at any time during the run. These "snapshots" of data can be analyzed using the graphing capabilities with Micro Saint or imported into another statistical analysis package. In addition, data can be collected at any time during the model run. Micro Saint includes automatic queue data collection. By turning on the data collection, at the end of a run you can automatically analyze queue data on the length of the queue, the average wait time, and the maximum and minimum wait times (see Figure 7).

Using the insights gained from the results of the simulation analysis, users can assess the relative merits of alternative solutions. Additionally, users can predict the impact of these solutions which subsequently leads to a better understanding of the costs and benefits.

6 MANUFACTURING

Micro Saint is used in the manufacturing industry to look at throughput, cycle time, optimal schedules and factory layout. With its ease of use and flexibility, Micro Saint is the ideal simulation tool for analyzing and reengineering such departments as accounting or even individual work cells.

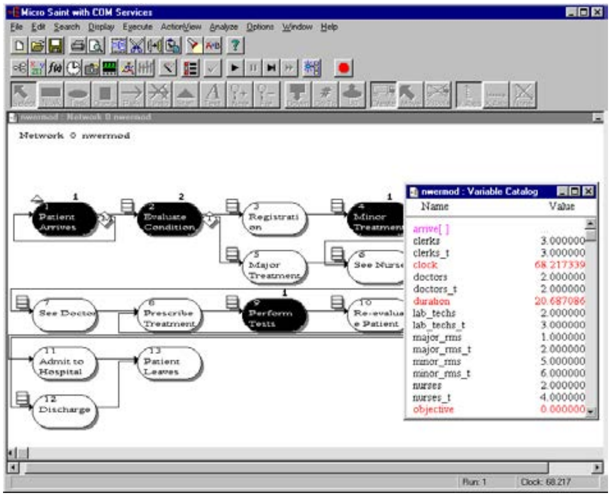

Figure 5: Micro Saint Symbolic Animation

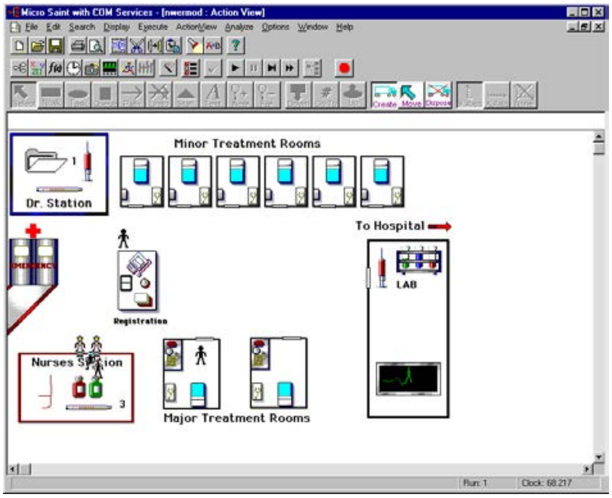

Figure 6: Micro Saint Action View Animation

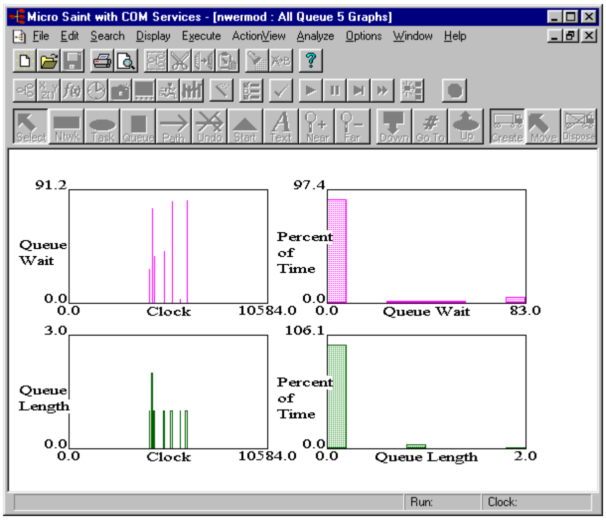

Figure 7: Micro Saint Automatic Data Collection Graphs

The Optimization feature in Micro Saint appeals to manufacturing facilities. For example, if a company is doing a simulation of their inventory system, the reorder point, the order quantity and the time between inventory reviews are the variables that define the system. The optimizer can help define the optimal inventory policy while minimizing a function of total expected cost.

For example, a Fortune 100 company had a cellular manufacturing layout that they felt could be made more efficient. They were about to make substantial capital improvements in manufacturing system equipment and wanted to make sure the new equipment was integrated with the old equipment in the best possible way. The company used Micro Saint to model their manufacturing system and to find a cellular layout that would meet their production goals. This study required a sophisticated model. The production goals were spread across 40 different product types and a JIT design was needed because of a limited capacity for inventory. The study was restricted to three weeks in length.

In the process of building the model, the customer gained an understanding of the system and realized many areas for potential improvement. The project did not attempt to discover the "optimal design" for the cell rather it only identified one of an entire family of solutions that would work. More models were built in order to simulate the other production line cells. These models allowed the customer to consider tradeoffs based on operator utilization balanced against the cost of the equipment, operator training, installation requirements, and process time. The bottom line was the manufacturer was able to increase production by 71% and increase profit per unit by 142%. This resulted in an increase in the annual profits of the company by over 400% on that single production line. The company reduced costs and improved quality with just a small investment in simulation.

7 HEALTH CARE

In the health care industry, Micro Saint has been used to look at emergency room flow, ambulatory services, OBGYN units, pharmaceutical processes and patient file flow. Because customers often choose health care facilities on the basis of the quality of service they receive, every hospital or health care organization must analyze questions about cost versus quality. Simulation is one way hospitals are able to answer these questions. In one instance an Ambulatory Surgery Department, the department that cares for patients both pre-operatively and post-operatively, had run out of space. The question was: How do we either build a new facility or redesign the existing space without changing the surgery schedule? Micro Saint was used to simulate the flow of patients from ambulatory surgery, to surgery, to recovery, and back to ambulatory surgery. A management engineer simulated the effects on many different alternatives for routing patients through the system and maximized the utilization for the facilities.

The hospital staff was so pleased with the recommendations made for the ambulatory surgery facilities that the management engineer was asked to help evaluate the surgery schedule on a daily basis. The changes recommended through the simulation models allowed the hospital to increase the number of patients that can be scheduled for ambulatory surgery, therefore increasing profits while improving the quality of service being offered to patients. This is just one example of how Micro Saint can help improve patient care and reduce costs at a hospital.

8 HUMAN FACTORS AND ERGONOMICS

The use of simulation to analyze human factors and ergonomics is a relatively new application of simulation. Some decisions that could be evaluated include “How many crewmembers are needed to fly an airplane?” and “What will the availability of trucks be for a given number of maintainers of given skill types?”

Simulation techniques have been developed to answer these questions as a function of equipment design factors. For example, during the early design phases of the Army Comanche helicopter, one of the key objectives was that the aircraft be piloted and operated entirely by one human. Four different helicopter designs were simulated using Micro Saint to determine whether a one-person cockpit design would cause the operator’s workload to reach unacceptable levels during the mission. Variables and modeling constructs were included in these models to track operator workload demands in the visual, auditory, cognitive, and psychomotor aspects of the operator’s tasks. For each design, operator workload was predicted and the tasks driving workload were identified. The advantages of each of the alternatives were identified. Ultimately, it was recommended that a one-person cockpit was not feasible with the technical and other design constraints.

9 SUMMARY

This paper has focused on the Micro Saint methodology and the underlying principles of modeling with Micro Saint in a variety of different industries. Micro Saint is a powerful tool used for evaluating the dynamic aspects of systems within a wide variety of application areas. Micro Saint’s primary strength is that is has an intuitive graphical interface that allows users to quickly develop models that accurately represent their system. Users are then able to evaluate “what if” scenarios with a variety of inputs to find the optimal solution. With simulation becoming a more widely used technology, better decisions can be made, money can be saved, productivity can be increased and customers can receive a higher level of service.

Not all of the software features for building models, controlling a simulation and generating and analyzing data have been covered, for more information please contact Micro Analysis and Design

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