SIMULATION MODELING USING PROMODEL TECHNOLOGY

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ABSTRACT

PROMODEL's simulation modeling products are powerful yet easy-to-use simulation tools for modeling all types of systems and processes. ProModel® is designed to model manufacturing systems ranging from small job shops and machining cells to large mass production, flexible manufacturing systems, and supply chain systems. Other simulation products available from PROMODEL Corporation include MedModel®, ServiceModel®, Innovate™, and ProModel PI™ (for process improvement). PROMODEL products are Windows based applications with intuitive graphical interfaces and object-oriented modeling constructs, eliminating the need for programming. They combine the flexibility of a general-purpose simulation language with the convenience of data-driven simulators. This paper provides an overview of ProModel and presents its modeling, analysis, and optimization capabilities.

1 OVERVIEW OF PROMODEL AND MEDMODEL

ProModel is a simulation and animation tool designed to model manufacturing systems of all types quickly and accurately. Engineers and managers find the manufacturing oriented modeling elements and rule-based decision logic extremely easy to learn and use. This ease of use does not, however, come at the cost of flexibility; ProModel is capable of modeling even the most complex systems. Because it provides such an intuitive and straightforward approach to modeling, it is also attractive to professors in engineering and business programs who are interested in teaching modeling and analysis concepts without having to teach computer programming.

While most systems can be modeled by selecting from ProModel's complete set of modeling elements (e.g. resources, downtimes, locations, etc.) and modifying the appropriate parameters, complete programming capability is also provided if needed for modeling special situations.

Built-in language features include if-then-else logic, Boolean expressions, variables, attributes, arrays and even access to external spreadsheet and text files.

For those who prefer coding complex logic using a programming language such as C++ or Visual Basic, external subroutines may be dynamically linked to the model and called from anywhere inside the model at runtime. ProModel may also be controlled as a COM object, and run directly from external applications such as Microsoft Excel or PowerPoint, or from custom front-ends such as a VB interface. In this way, ProModel allows all members of the decision-making team to use the tools they are most comfortable with, providing total flexibility.

ProModel also provides several built-in distribution functions, which, in conjunction with streams, return random values according to a statistical distribution. To aid the user in selecting an appropriate distribution for a data set, Stat::Fit is included with ProModel. Stat::Fit is a curve fitting software that fits analytical distributions to user data.

Model development is completely graphical and object-oriented. To the greatest extent possible, all input is provided graphically with information being grouped by object type and presented in a "spreadsheet-like" format for quick and intuitive access. For example, when the modeler defines a machine the modeler can also define the machine's icon, capacity, downtime characteristics, input and output rules, desired output statistics, etc.

ProModel complies with Graphical User Interface (GUI) standards, which means that individuals familiar with other standard Windows programs such as word processors or spreadsheets will have no trouble learning how to use ProModel. This data input approach minimizes the learning curve for beginners and maximizes the efficiency for modifying large and complex models.

A unique feature in ProModel is the ability to invoke pop-up menus, depending on the current context, that prompt the user in defining any statement or expression. This Logic Builder enables any expression or statement to be entered using only the mouse. It also eliminates the need to remember variable or other element names that us-

ers wish to reference by allowing name selection from a list box.

Convenient online documentation is available through ProModel's integrated Help system and online tutorials. The Help system uses the Windows Help system that allows maximum flexibility for looking up anything from command syntax to descriptions of model building modules. ProModel also provides tutorials that contain quick lessons on how to build models, run models, access output reports, and how to model various applications with the software.

To further reduce model development time, ProModel provides model merging capabilities to allow several individuals to be working separately on different sections of a large model. Additionally, frequently defined cells or even commonly used decision logic may be stored as submodel templates which eliminate the need to "re-invent the wheel" with every model. These templates can even have specially designated parameters that may be changed by the user.

Animation development is integrated with the model definition. A major drawback of many simulation software products is that their animation development is independent from simulation model development. This makes it time consuming and inconvenient for engineers to use animation as a validation/verification tool. ProModel integrates system definition and animation development into one function. While defining routing locations, conveyors, AGV paths, and other elements, the user essentially develops the animation layout. The layout screen is a virtual screen that can be scaled to an actual factory layout.

Simulation results are informative and may be displayed in tabular or graphical form. Many other simulation software products require special commands to generate statistics that are difficult to interpret for non-simulationists. ProModel allows quick and convenient selection of reports and provides automatic tabular and graphic reports on all system performance measures. Output reports from several simulation runs can even be compared on the same graph.

ProModel runs on any standard Pentium® or faster computer with Windows 95, Windows 98, Windows NT, Windows 2000, or Windows XP operating systems. Licensing is available for single-user "standalone" platforms as well as network licensing versions. ProModel does not require any special graphics cards or special monitors, making it convenient and cost effective for companies and academic institutions using standard microcomputers.

2 MODELING ELEMENTS

The modeling elements of ProModel provide the building blocks for representing the physical and logical components of the system being modeled. Physical elements of the system such as parts, machines, or resources may be referenced either graphically or by name. Figure 1 illustrates the pull-down menu system utilized to access the various elements of the model. Names of modeling elements may be any word consisting of up to 80 alphanumeric characters. Following is a brief description of each of these elements.
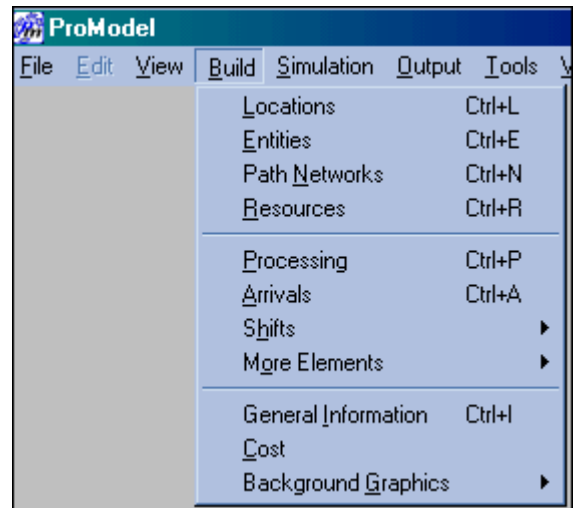

Figure 1: ProModel's Modeling Elements

2.1 Locations

Locations are fixed places in the system such as machines, queues, storage areas, workstations or tanks to which parts or entities are routed for processing, storage or simply to make some decision about further routing. Locations may be either single unit locations (a single machine) or multi-unit locations (a group of similar machines performing the same operation in parallel).

Locations may have a capacity greater than one and may have periodic downtimes as a function of clock time (shift changes), usage time (tool wear), usage frequency (change a dispenser after every *n* cycles), change of material (machine setup) or other user-defined condition. Locations may be assigned input and output rules. Input rules are used for selecting what entity to process next, while output rules are used for ranking entities (i.e. FIFO, LIFO, user-defined) in a multi-capacity location.

Two special types of locations that provide movement and perform holding and operation functions are queues and conveyors. A queue mimics the behavior of waiting lines, including the movement of entities through the line. Conveyors are accumulating or non-accumulating and have a particular speed and load spacing. Conveyors may be configured together to provide conveyor networks.

ProModel also has the ability to schedule independent arrivals. This ability makes creating appointments easy, and appointments can be automatically repeated weekly or daily. Other features include the optimization of shift and arrival patterns, and the ability to group resources and collect statistics on the group. ProModel also has an on-screen

24-hour clock and calendar, plus several functions associated with this clock which provide access to calendar days (including the day of the month), calendar month, and calendar year.

2.2 Entities (or Parts)

Entities or parts refer to the items being processed in the system. These may include raw materials, piece parts, assemblies, loads, WIP, finished products, orders, or any other type of product that may need to be tracked as it moves through the system. Entities of the same type or of different types may be consolidated into a single entity, separated into two or more additional entities or converted to one or more new entity types.

Entities may be assigned attributes that can be tested in making decisions or used for gathering specialized statistics. The graphic of an entity can be changed as a result of an operation to show the physical change during the animation.

2.3 Path Networks

Path networks are optional and define the possible paths that entities and resources may travel when moving through the system. Path networks consist of nodes connected by path segments and are defined graphically with simple mouse clicks. Multiple path networks may be defined, and one or more resources and/or entities may share the same network. Movement along a path network may be defined in terms of distance and speed or by time. Path distances are automatically computed based on the layout scale defined by the user.

There are three types of path networks: passing, non-passing, and crane. A passing network is used for open path movement where entities and resources are free to overtake one another. Non-passing networks consist of single-file tracks or guide paths such as those used for AGVs where vehicles are not able to pass. Crane networks define the operating envelope and interface points for bridge cranes.

2.4 Resources

A resource may be a person, tool, vehicle or other object that may be used to:

- Transport material between routing locations,
- Perform an operation on material at a location,
- Perform maintenance on a location or other resource that is down.

Resources may be either static or assigned to a path network for dynamic movement. A special type of dynamic resource is a crane. Built-in decision rules can be used for allocation of resources and for prioritization of part pick-up and delivery. Motion characteristics of resources such as empty and full speeds, acceleration, deceleration, and pickup and delivery time can also be specified.

2.5 Processing (or Routing)

This element defines the processing sequence and flow logic of entities between routing locations. The operation or service times at locations, resource requirements, processing logic, input/output relationship, routing conditions, and move times or requirements can be described using the Processing element.

Operation times can be defined by constants, distributions, functions, attributes, subroutines, etc. or an expression containing any combination of these. Operation logic can include IF-THEN-ELSE statements, loops, nested statement blocks and subroutine calls. Resource related statements such as GET, USE, and JOINTLY GET with Boolean expressions and built-in operation statements such as ACCUM, JOIN, and GROUP greatly simplify otherwise complex logic in describing the processing requirements. Built-in and user-defined routing rules provide flexibility for modeling all types of routing conditions.

2.6 Arrivals (or Production Schedule)

Deterministic, conditional, or stochastic arrivals can be modeled using this element. Independent scheduled arrivals simulate scheduling of repeated appointments and production schedules can be modeled using independent arrivals. External files including production schedules or arrival data can be read into ProModel in the Arrivals element. Built-in distributions, user-defined distributions, or spreadsheet created data can be used to define arrival times and quantities.

2.7 Shifts (or Work Schedules)

A powerful feature is the ability to define custom work and break schedules through ProModel's Shifts module. Work and break schedules are defined graphically by time of day and day of the week. Resources or locations are then assigned to a specific shift schedule. In addition, the user can define shift and break logic that controls location and resource behavior when they go off-line and also controls what happens within the model once the resources are off-line.

3   ADDITIONAL MODELING ELEMENTS

ProModel provides additional modeling elements used in statements and expressions to define special decision and operating logic in a model. These elements include vari-

ables, attributes, functions, user-defined distributions, and costing.

There are several types of logic elements that may be defined by the user. Like model elements, names given to these elements may be up to 80 characters in length. Figure 2 shows the menu for accessing these additional elements, some of which will be discussed below.
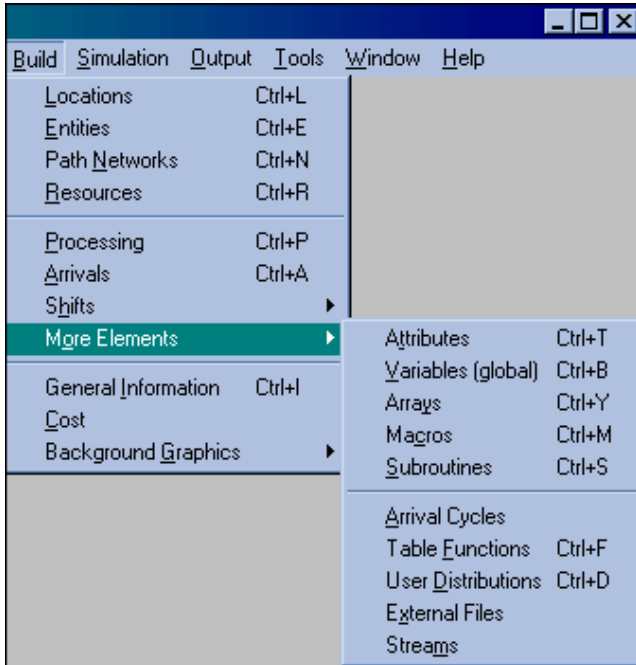

Figure 2: More Elements Menu

3.1 Attributes

Attributes are placeholders assigned to an entity or location. Attributes contain numerical information about particular entities or locations. Attributes are assigned user-defined alphanumeric names and numeric values that may be real or integer. Attributes may be useful containers of information such as routing priority, entity speed, conveyor speed, or entity model number.

3.2 Variables

Variables are used for decision-making and statistical reporting. The value of a variable may be monitored over time and displayed at the end of the simulation as a time series plot or histogram. Variables may hold integer or real values. Local variables may also be used for quick convenience when defining logic.

3.3 Arrays

An array is a matrix of variables representing multiple values and may be one-/multi-dimensional. ProModel 4.2 has the ability to directly import Excel spreadsheet data into arrays. This improves data accuracy and allows for easy updates to processing data. Array data may also be directly written to Excel spreadsheet format for manipulation of results in a familiar environment.

3.4 Macros

A macro is a complex expression or set of expressions that can be defined once and used multiple times as part of a logic statement (i.e. processing, scheduling, downtime logic). Macros are helpful when the same bit of logic is repeated in many places in the model.

3.5 Subroutines

A subroutine is a user-defined block of statements that can be passed values when called and optionally return values when completed. Subroutines may be referenced in the place of any value or logic. A complex operation performed several places in a model may be appropriately defined by a single subroutine.

3.6 Arrival Cycles, Table Functions, and User Defined Distributions

Arrival patterns, table functions or user distributions may be defined. For example, a user defined distribution that returns an operation time of 5 minutes 30 percent of the time and an operation time of 8 minutes 70 percent of the time can be expressed in the User Distributions element.

3.7 External Files

One of the powerful features of ProModel is the ability to read data from external text or spreadsheet files or write data to external files. For example, operation times (even in the form of expressions) from an Excel spreadsheet file can be read into ProModel using this element.

4   COSTING

With ProModel's Costing feature, users can make decisions about their system on a cost basis. Users can monitor costs associated with locations, entities, and resources during a model run. In addition, the General Statistics Report includes Costing statistics, automatically generated at runtime. For locations, the user can find the cost of operating a location. For resources, the total cost includes the usage cost as well as the cost of not using the resource. For entities, the total cost includes the costs incurred at all locations the entity passed through, the costs incurred by use of resources, and the initial cost of the entity.

5 GRAPHICS

Graphics in ProModel are realistic and easy to create. Visually realistic animation helps simulation to become an effective communication vehicle between engineers and managers. ProModel comes with an extensive library of graphics with provision to create and add other graphics to the library. ProModel's Graphic Editor comes with a complete set of drawing tools and a full spectrum of color selections. Scaling, rotating, copying and many other editing features are available. You can even import drawings from other graphics packages. With little effort you can develop quick and simple 2D layouts, or, with little extra effort, 3D perspective layouts. CAD layout drawings (e.g. AutoCAD) can also be brought in to use as the model background. The Graphic Editor is shown in Figure 3. If true 3D modeling is important to your application, you may want to consider our Innovate product (not shown here, but available).
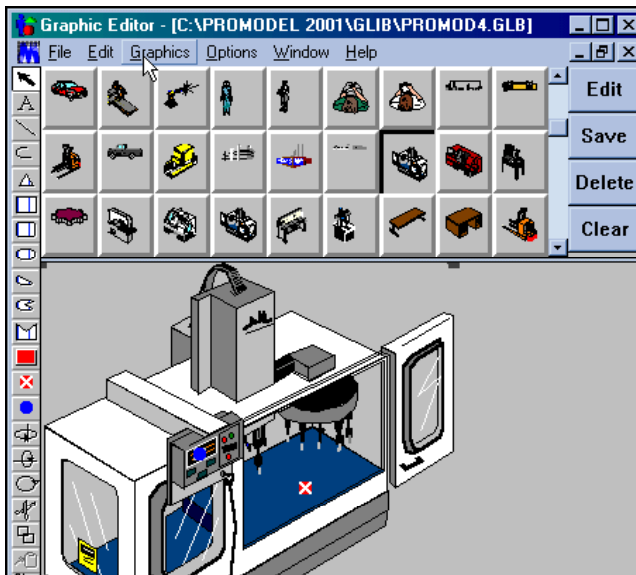

Figure 3: ProModel's Graphic Editor

6 SCENARIOS AND RUNTIME INTERFACE

The runtime interface (RTI) is a convenient and controlled environment for modifying selected model parameters (capacities, operation times, etc.) without having to change the model data directly. It also provides an experimental environment, which permits multiple scenarios to be defined and simulated. The RTI can be accessed at the beginning of a simulation run for making modifications for a single run or for saving alternative modifications as scenarios for running multiple scenario analysis.

7 RUNNING THE SIMULATION & ANIMATION

Models can be run for specified lengths of time or until all entities have been processed. Multiple replications may also be specified. Models may be run with or without animation. The animation is very smooth and maintains great resolution at any zoom factor.

The Views feature allows the modeler to define and then access specific areas of the model layout quickly and easily. Selecting a view scrolls the layout window and adjusts the zoom so the observer sees a specific region of the layout regardless of the layout window's size. Once a view is defined, it can be selected manually while the animation is running or may be changed automatically from within the logic.

During the simulation the status of resources or the current value of any logic element may be displayed. Source level debugging allows the modeler to trace each action with the option to display the actual source statement that triggered the action. Trace statements may be confined to a single area of a model. Status lights for locations change colors to help the observer see various states such as busy, idle or down.

ProModel's Dynamic Plot feature (Figure 4) provides for graphical observation of statistical information during runtime, as well as the ability to export this information to an Excel spreadsheet. This statistical information can be charted in 2D or 3D mode, or as a line, bar, step, area, curve, or Gantt chart.
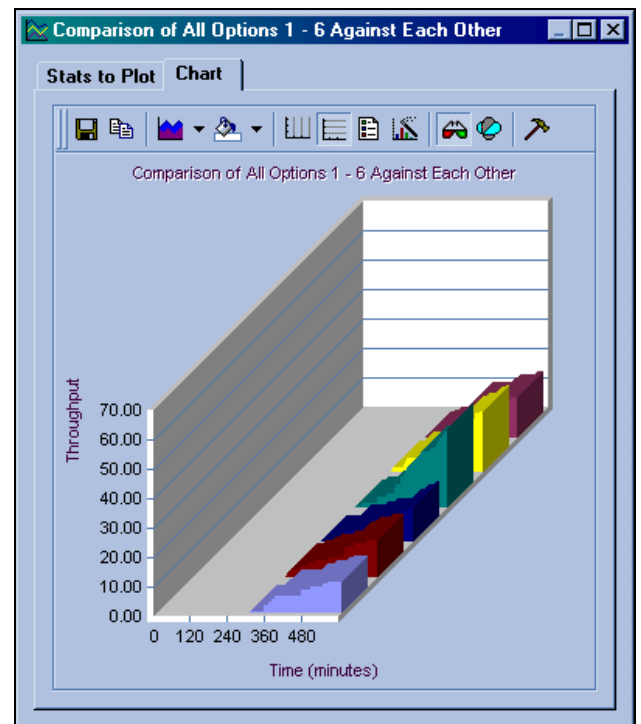

Figure 4: Dynamic Plots

ProModel's animation screen is a virtual screen. This means the animation layout is limited only by memory in the computer. By turning off the animation, users can speed up the simulation, run for a while and then turn the animation back on. The simulation clock resolution can be expressed in terms of hours, minutes, or seconds with a clock resolution of .00001 second.

8   OUTPUT REPORTS

Users can customize their output reports by selecting the type of statistics desired for each resource, location, entity, or variable. The statistics are written to a results database that can be saved as an Excel spreadsheet, or automatically converted to Access database tables. Additionally, graphic reports of the outputs can be displayed, printed, plotted, or pasted into other programs. These graphs can be individual or comparative pie charts, histograms, or time-series plots. Figure 5 contains a sample location state graph.
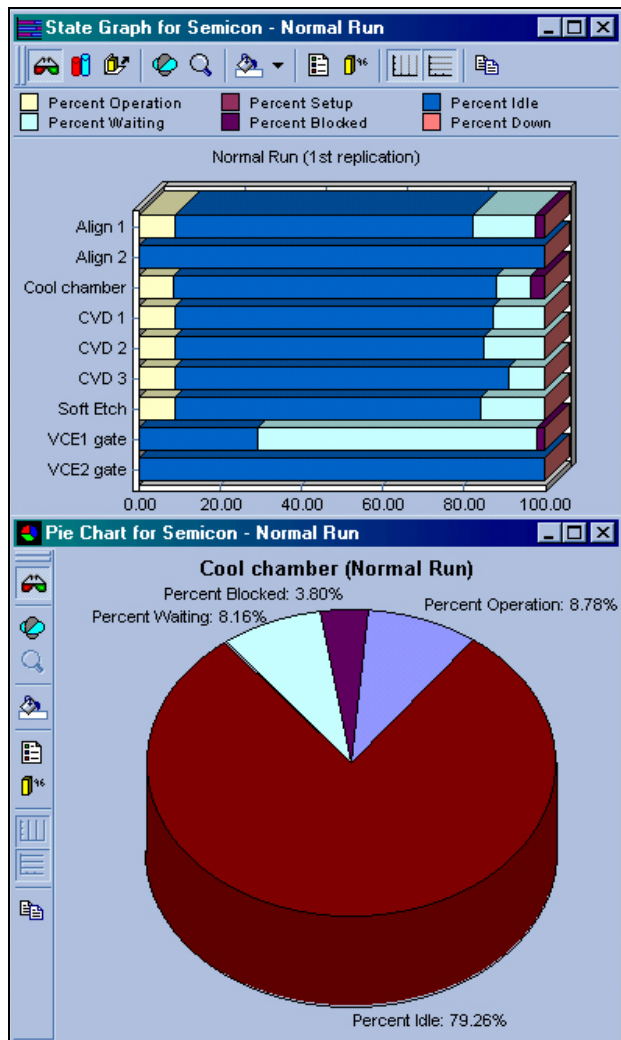

Figure 5: Location State Graphs

9   OPTIONS

ProModel provides for customizing the modeling environment to suit the preferences of the user. Under the View menu, they can zoom in or out, display a grid, set default directories for model files, icon library files, or model output files. Users can set and save default settings (i.e. window sizes, appearance). ProModel also allows them to choose editing preferences for model development. Default fonts and sizes for text and a choice of long or abbreviated menu lengths are available. Prompts and added explanations can also be activated which may assist the novice user. The expert user can benefit from choosing options that streamline the editing process.

10   OPTIMIZATION

SimRunner Optimization is an add-on capability for ProModel simulation software. SimRunner turns a simulation model into a solution machine by giving the best answer possible in the least amount of time. The optimization process takes an existing ProModel simulation model and performs sophisticated "what-if" analysis and optimization automatically. For each optimization project, the modeler tells SimRunner which model to analyze/optimize, which input factors to change, and how to measure system simulation performance. You can run two types of projects in SimRunner: Model Analysis, and Model Optimization. Model Analysis helps to determine the number of replications needed to estimate the mean value of the objective function to within a specified error and confidence level and assists in determining the warm-up time and run time for the model, which aids in understanding of the steady-state behavior of the objective function. Model Optimization is a multi-variable optimization that tries various combinations of input factors to arrive at the combination that provides the best objective function value. The SimRunner Output report generates the following three types of data and reporting:

1.   Data reports for import into spreadsheets
2.   Analysis reports for text and word processing reports
3.   Charts for graphical display of results.

11   CONCLUSIONS

PROMODEL products continue to provide quality solutions using the latest in simulation technology. ProModel is an excellent tool to reduce costs, increase capacity, and improve customer service. ProModel is making simulation a standard method for providing insightful, relevant, and beneficial answers to engineers, managers and systems analysts. PROMODEL Corporation provides the tools to model complex systems accurately and with confidence in the results.

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