

THE WITNESS[®] TOOLBOX – A TUTORIAL

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ABSTRACT

Advanced simulation software packages can no longer stand alone. Simulation professionals are demanding a toolbox of advanced capabilities and add-on products to allow quick and efficient model building, enhanced graphical displays, and accelerated experimentation and optimization procedures. With the release of WITNESS Release 9, upgrades to the WITNESS^{VR} virtual reality module and Optimizer[®] optimization module, Number Cruncher[®], and SIMplicity[®], Lanner Group offers many new options to make model building easier, make graphics more appealing, and produce statistically accurate results quicker and with more impact.

1 INTRODUCTION

The premise of this paper is to introduce the practicality of a “toolbox” of simulation tools for use within a manufacturing facility. These tools can be applied to a proposed system, or to the re-engineering of an existing system. By using this suite of tools, you allow a team of people to take a look at a process from many different viewpoints, and to solicit the input of various people within an organization, before arriving at one solution everyone can live with. The process comes to completion as presentation-quality simulation tools are used to communicate ideas to those who make the final decision, i.e., upper management, investors, CEO’s and CFO’s.

The products that comprise this suite of tools include WITNESS simulation software, WITNESS OPTIMIZER, WITNESS^{VR} virtual reality software, and SIMplicity. These products are available from Lanner Group, Inc., a leading international manufacturer of decision-support software

2 WITNESS SIMULATION SOFTWARE

WITNESS is a true process simulation and modeling tool, for evaluating the interaction among different product lines that may share a facility’s resources. WITNESS makes

obvious any production bottlenecks, overly-idle resources, storage areas that are too small or too large and any potential issues with respect to labor availability.

2.1 WITNESS Modeling Elements

The WITNESS simulation package is capable of modeling a variety of discrete (e.g., part-based) and continuous (e.g., fluids and high-volume fast-moving goods) elements, as described below. Depending on the type of element, each can be in any of a number of “states”. These states can be idle (waiting), busy (processing), blocked, in-setup, broken down, and waiting labor (cycle/setup/repair).

2.1.1 Basic Discrete Elements

The most basic discrete modeling elements are Parts, Buffers, Machines, and Conveyors.

Parts are simply objects that travel from one location to another. They may be pulled passively into the model by the simulation, pushed into the system by an active part arrival schedule, arrive from a part file, created via a “production” machine, or any combination of the above.

Buffers are passive storage areas of finite capacity. Buffers can be configured as “delay” buffers, where parts must stay in for a minimum amount of time. They can be configured as “dwell” buffers, where parts cannot stay in the buffer any longer than a specified time. A part can be ejected from a buffer if it violates any of these conditions. Combinations of First-In-First-Out / Last-In-First-Out sequencing are possible, as well as the ability to have parts pushed to and pulled from locations in the buffer other than the front and rear.

Machines are the workhorses of WITNESS. A variety of machine types are available:

- Single
- Batch
- Assembly
- Production
- Multiple-Cycle
- Multiple-Station

Machines can be defined with Setup and Breakdown parameters, useful for modeling real-life failures, retooling, preventive maintenance, etc.

Conveyors are defined by a length in parts and an index time which represents the time it takes a part to move from one position on the conveyor to the next. Parts can be pushed to and pulled from any position on the conveyor. The conveyor itself can actively pull parts from the rear and push parts from the front. Conveyors may be fixed or queued. A fixed conveyor maintains the space between parts if the part on the front of the conveyor is blocked. By contrast, a queuing conveyor allows parts to compact together even though the conveyor may be stopped. Other discrete elements include:

- tracks and vehicles
- labor
- shifts
- variables
- part attributes

2.1.2 New Features

New, more complex elements now allow for easy modeling of Power and Free conveyor systems. Customizable arrival patterns, aimed primarily at the service sector, allow easier entry of complex paperwork generation profiles or customer arrivals at hospitals, banks, and supermarkets. A new tree structure is used for element creation and selection, allowing longer element names, ease of use in editing names and quantities of elements, and right mouse access for detailing, displaying and cloning elements. WITNESS reports and charts have a functional grid structure which can be easily sorted and pasted to a spreadsheet or word processor.

2.1.3 Continuous Elements

Continuous elements are used whenever the movement of parts is represented by a flow rate, rather than the movement of individual parts. Typical materials used in a continuous simulation model might be fluids, powders, gases, or any high-volume fast-moving part. A good example of high rate part production, more suitable for continuous simulation modeling, might be small individual candies, nails, screws, bottle caps, etc. Other scenarios appropriate for continuous modeling might include the processing of large rolls of sheet metal, wire, adhesive tapes, paper, etc.

Fluids, Tanks, Processors, and Pipes comprise the WITNESS continuous flow modeling elements. Fluids and their resulting flow rates are usually measured in volumes or weights, the exact units of which are chosen by the user. It is common to use weights or volumes. Any unit may be used, as long as usage is consistent throughout the simulation.

A Tank stores fluid and is analogous to the Buffer element in discrete processing. A user indicates tank capacity and input and output flow rates. The flow rate is expressed in user units over simulation time units (such as gallons per hour, liters per minute, cubic centimeters per second, etc.). Warning levels can be set on rising or falling, allowing user actions to be taken under certain conditions. Just as machines can be repaired and retooled, tanks can also be configured for a cleaning cycle when required.

The Pipe element moves fluid from one location to another, and is analogous to the conveyor element in discrete processing. Pipes have input and output flow rates, and a maximum volume specification, that determines how long it takes a given fluid to go from one end of the pipe to the other, given the assigned flow rate. Pipes can have breakdowns associated with them, for modeling such events as bursts, leaks, or other periodic downtime. Pipes can also be scheduled for cleaning or purging, independent of the breakdowns. A pipe can be configured for fluid flow from it even though there may be no volume arriving at the other end. The ability for fluid to empty from a pipe even though there is no arriving fluid, allows for convenient modeling of gravity-fed material handling systems for fluids, powders, and small objects. The operation of valves (on, off, partially closed, etc.) is easily modeled simply by toggling the flow rates into and out of tanks, pipes, and processors, from a positive flow rate to zero.

The Processor element is analogous to the machine element in discrete processing. The processor first fills to capacity (or to a specified processing level), then processes the fluid for a given amount of time, then empties completely. Common uses of the processor are to simulate agitators and mixing machines, aerators, fluid separators, degassing equipment, gas injection equipment, etc. Processors, as well as tanks, will show the proportional mix of two or more fluids. Processors can be configured for cleaning cycles, as well as breakdowns. Like tanks, processors can also trigger warning level alarms.

Finally, it is possible to mix fluids with parts in the discrete machine element. This feature is commonly used when filling vessels with fluid (paint cans with paint, bottles with soft drinks, etc.)

2.2 WITNESS Graphical User Interface

The WITNESS user interface is Windows compliant. The primary interface to the software is either pulldown menus or a button tool bar. The operation of the simulation model is controlled at the bottom of the screen, from a toolbar which starts, stops, and resets the model.

The majority of the activity however, takes place in the Simulation Window. It is here that items are placed in drag-and-drop fashion. The Designer Elements are commonly used to quickly drag-and-drop pre-defined items onto the simulation screen. After the required

elements are on the screen, visual Push and Pull rules are added, via the mouse.

Once a basic model has been assembled on the screen, the next step is to add more detail to elements in the model. These details are communicated to WITNESS via a detail dialog box. It is from this detail dialog that all of the logic for an element is entered. The detail dialog can be invoked by double clicking with a mouse on any element on the screen.

While the Detail dialog controls the logic of the model element, the Display dialog controls how it looks. From the Display dialog, one can control any visual aspect of the modeling element, such as the icon to be used, text font, color, and an assortment of other items which can be attached to the display of each modeling element. The display dialog can be invoked by double right clicking on any element on the screen.

Standard WITNESS reports can be viewed on the screen either in tabular or graphic format. In addition, several graphical elements are available for summarizing statistics from a model. Pie charts, timeseries and histograms provide a meaningful, easily read format for data from a simulation model run. In addition, data can be read from and written to external files.

A WITNESS model has associated with it up to 500 icons, which can be used to represent elements on the screen. In addition, a screen editor allows a user to add text and other graphics to a display. Bitmap files can be imported into a WITNESS model as an icon, and AutoCAD dxf files can be imported to provide a shop floor layout to be used as a backdrop for a model. Audio and video clips can also be activated from within a WITNESS model.

2 WITNESS OPTIMIZER: FINDING THE OPTIMUM SOLUTION

WITNESS Optimizer provides a plug-in module which can intelligently test different combinations of changes within a model, and carry out the desired experimentation. The resulting answer pool provides the ability to use one set of results as the basis for a new search looking at different parameter settings, increased constraints or the application of a different algorithm. The Optimizer will indicate the “best” model based on an objective function provided by the model builder. This objective function quantifies the objective of the optimization.

In addition, a user provides information on any constraints within the system, i.e. factors within the model which can vary, and what their range of variation is. Model run-length, as well as number of replications, is also indicated by the user. More sophisticated users can choose from several different search methods to be used in arriving quickly at the optimum.

3.1 Preparing a Model for Optimization

An objective function is defined as a normal WITNESS function. It takes no parameters and returns a numeric result, either integer or real. Generally, it is some function of current values of the optimization variables and results of the simulation. An example objective function might be:

value of throughput – cost of machines – cost of staff.

During the optimization process, different aspects of the model are varied, and the resulting value for the objective function will be compared to previous values to see if any improvement has taken place.

3.2 Running the Optimizer

A model optimization dialogue provides a means for users to select from several different objective functions they may have specified, and to indicate whether the function should be maximized or minimized. Optimization variables can be added or removed from a list of those available. Each variable has a range of possible values or a discrete set of possible values. Any number of variables can be considered during optimization. In addition, a user can manage constraints within a model to reduce the total number of possible combinations of values. Constraints are expressed as linear functions of two or more of the optimization variables. For example:

staff1 + staff2 <= 10.

Any number of constraints can be included in an optimization scenario.

For a given optimization run, the user can indicate a warm-up period (a period after which statistics are zeroed out, and a model run continued), the length of a run (in simulation time units), a number of replications, and information on how random numbers are to be varied for each replication. Information is provided on the variability of statistics for these replications, providing the user an indication of the statistical stability of the model.

Several optimization methods are provided, ranging from simply running all possible combinations to more complex algorithms. Available methods are:

- All combinations
- Min/Mid/Max – runs 3 evaluations based on minimum, midpoint and maximum values of all variables
- Hill Climb – generates random iterations which are accepted if of higher quality and rejected if not.

- Random solutions – generates random combinations of variable values
- Adaptive Thermostatistical SA (simulated annealing) – less dependent than the Hill Climb method on the starting values chosen and less likely to get “stuck” at a local optimum. Sophisticated users may manually adjust the search parameters.

Output from an optimization scenario is in the form of tables and graphs of best results. Information is also provided on variance, confidence limits and “t” tests. In turn, the output from an optimization run can be used to set values in a model, and the entire optimization scenario can be saved for later analysis.

3.3 WITNESS Number Cruncher[®]

WITNESS Number Cruncher is a valuable low-cost accessory to the busy simulation practice. It combines the value of a run-only license with the power of the Optimizer. It provides you with the capability to quickly perform batch experimentation and optimization on a second computer, while you continue with other model-building tasks.

4 WITNESS^{VR}: VISUALIZING AND COMMUNICATING VIA VIRTUAL REALITY

Once a WITNESS model has been completed and meaningful results emerge, it may be desirable to create a 3D Virtual Reality version of the model. It is from this VR model that people not familiar with WITNESS can begin to more easily understand the underlying logic of the simulation.

To create a 3D view from a 2D view, the WITNESS VR fast-build facility is used. The fast-build takes the 2D model icon locations and creates a 3D VR world by placing 3D objects into those locations, in a separate view. The 3D objects selected for each 2D icon are found in a reference file containing a number of default 3D objects.

The result of creating a VR world is that the user is free to fly around the created world and view it as it runs. By doing this, the viewer has a much better understanding of what is happening in the simulation. Many times, a WITNESS simulation is created rather schematically, and although very understandable to the people who wrote the model, may not be understandable to those not closely associated with the project. Therefore it is of great benefit to have on-hand a version of the model which runs in a very realistic, Virtual Reality mode.

The VR module comes with the ability to create and edit objects and virtual worlds. It also has the ability to attach a camera to an object, and follow that object through the VR world as the simulation runs. This has the visual

impact of following a part through the simulation from beginning to end.

New features of the Virtual Reality module center around the unique Fastbuild facility which takes any WITNESS model and creates an automatic 3D view. New features of Fastbuild dramatically improve the realism of the created factory/process scene. Machines, conveyors and other VR objects can be manipulated in either the 2D or the VR view after Fastbuild. The VR module offers full 3D capability for the new Power and Free Conveyor elements in WITNESS.

5 SIMPLICITY[®]

An alternative to WITNESS, SIMPLICITY has been developed to fulfill the demand for a quick, easy and low cost simulation tool for the non-specialist, but can also be a useful tool for the experienced simulation user. SIMPLICITY can be looked upon as a dynamic flowchart for modeling processes, whether they are service or manufacturing oriented. SIMPLICITY uses a diagrammatic approach to modeling, with a flowchart style. It offers intelligent support to the modeler in linking the model in flowchart form. SIMPLICITY is completely mouse-driven, with point and click options for model logic. It provides a standard set of reports which can be manipulated in a spreadsheet.

6 CONCLUSION

From WITNESS, to Optimizer and Number Cruncher, to the Virtual Reality module, to SIMPLICITY, we have demonstrated how a suite of simulation tools can be used to model any process within an organization. Simulation professionals now have a variety of technical tools at their disposal. The completion of a timely and efficient simulation study involves assessing the project, choosing the correct set of tools for the job, and using them in the most efficient manner.