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Osman Balci, Randall P. Sadowski, Richard E. Nance (eds.)

A TUTORIAL ON WITNESS

Charles Murgiano

AT&T ISTEL Visual Interactive Systems
25800 Science Park Drive
Beachwood, Ohio 44122

ABSTRACT

WITNESS is a computerized simulation system designed for modeling manufacturing operations. It utilizes a graphical interface, menus and high-level elements so a non-specialist user can build, validate and experiment with models very quickly.

This paper explains the user interface, the steps used to build a WITNESS model and the features most useful for testing and running the model. It concludes with a brief description of some of the techniques that can be used in making fast, flexible models.

1. OVERVIEW OF WITNESS

Manufacturing operations provide a rich seam of applications ideal for simulation. Competitive edge can only be gained by modernizing equipment and methods with limited budgets and without lengthy on-line testing. Simulation is perfect for modeling change without disrupting production.

The main drawback to the use of simulation has been the difficulty involved in model building. Projects simply have taken far too long to complete for simulation to be considered a viable technology for the average manufacturer. Although most projects include basically the same components (value-added operations, material handling, labor, etc.), these basic components needed to be re-specified for each modeling project. Also, batch computing technology robbed modelers of a friendly user interface and the ability to employ an iterative approach to simulation.

WITNESS employs a fully interactive, visual approach to modeling and uses pre-defined element types to represent manufacturing processes. There are three main phases involved in building a WITNESS model, Define, Display, and Detail. At any point in creating a model, the user may enter into a Run mode and execute the portion of the model just built. The user can just as easily switch out of the Run mode and continue to modify or add to the model. Any change can be made in WITNESS at any time.

WITNESS modeling elements are created in the Define phase. In the Display phase, elements are positioned on the computer screen. In Detail, the modeler fills in templates to describe how elements operate and how they are connected to other elements. In Run, the simulation is executed. An animation of the model is displayed, and statistics are gathered simultaneously. Interactions can be used to learn more about the model once it is running.

The next four sections explain the steps involved in building and running a WITNESS model.

2. THE DEFINE PHASE

In the Define phase, physical and control elements are created.

2.1 Physical Elements

Physical elements represent manufacturing equipment. The physical elements are:

2.1.1 Parts

Individual items which are processed and move in and out of other elements. Parts may be introduced into a model according to a delivery schedule or on demand. Their routing may be specified by the operations that they pass through or by Part type. Attributes may be assigned to Parts to give them individual characteristics. They may contain quantities of Fluids.

2.1.2 Machines

Operations that are carried out on Parts. Machines get Parts, cycle and empty. They may breakdown and setup and Labor may be used to cycle, repair or set them up. Machines can assemble Parts together or split them into sub-components. They may be used to put Fluid into, or remove it from, Parts.

2.1.3 Buffers

Storage areas for Parts. As well as first-in-first-out, the Parts in a buffer may be sorted as they enter and chosen according to their attributes. The minimum time that a Part must spend in a buffer before it can be removed may be specified.

2.1.4 Conveyors

Transportation devices for moving Parts from one location to another. They may be accumulating or fixed pitch. They may breakdown and require Labor to repair them.

2.1.5 Labor

Resources that are required to operate, repair or set-up other elements. Labor may answer demands in the order in which they are received or jobs may be given priority according to their importance.

2.1.6 Vehicles

Material handling devices that load Parts, move along Tracks and unload the Parts. They have speeds, capacities and may be given acceleration and deceleration times.

2.1.7 Tracks

The paths along which Vehicles travel. They have a physical length and may be used to specify where Vehicles load and unload Parts.

2.1.8 Fluids

Material that flows through the other elements in a model. They may be given an arrival rate. Fluids may be placed in or removed from Parts. Fluids are incompressible.

2.1.9 Processors

Vessels that obtain Fluid, process it and empty. They have process times and may break down and be cleaned. Labor may

be used for all the above stages. Warning levels may be set to trigger activities when fluid levels are reached.

2.1.10 Tanks

Storage for Fluids. They have a capacity, may be cleaned and may also use fluid levels.

2.1.11 Pipes

Transporters of Fluids from one element to another. They have capacities and a flow rate. They may break down and be cleaned.

2.2 Control Elements

Control elements are ways of storing and using manufacturing data or results from the simulation. The control/statistical elements are:

2.2.1 Attributes

Data associated with individual Parts. They may hold Integer or Real numbers or the names of other related elements.

2.2.2 Variables

Data associated with more than an individual Part. Again they may be Integer, Real or Name. They may be displayed on the screen.

2.2.3 Functions

Procedures that calculate and return a value or cause a series of commands to be carried out. They may return Integer, Real or Name values or may be Void in that they do not return a value. They may be given parameters in the same way as programming language functions and subroutines.

2.2.4 Distributions

In addition to the 13 in-built statistical distributions, customized distributions may be defined. Actual data is entered by values and frequencies. Integer, Real and Name data may be used and the sampling method may be discrete or continuous.

2.2.5 Files

ASCII data may be read into the model from a File or saved to a File. This is a means of using existing data without re-typing it. Also, files provide an open system for WITNESS. Data can be passed between WITNESS models or to other software systems.

2.2.6 Part Files

ASCII files that are used to specify a Part delivery schedule in terms of type, batch size, arrival time and order characteristics. Part Files can also be used to record the sequence and timing of Parts leaving the simulation.

2.2.7 Timeseries

Graphs showing changes in a value over time. The recording interval and display characteristics can be specified. Up to seven different values can be shown on the same set of axes. The graph will update itself as the model is running.

2.2.8 Histograms

Graphs showing the distribution of an expression or value. The graph will update the display of the distribution as the model runs.

3. THE DISPLAY PHASE

In the Display phase, WITNESS elements are drawn and positioned on the screen. WITNESS uses windows to view sections of a large virtual screen. The views may be magnified if you wish to see enlargements of sections of the model. The windows may be stretched and may overlap each other. You can "pan" or scroll across the virtual screen using the scroll bars at the edge of each window.

The model layout is built up by positioning elements with a mouse. Characteristics such as the locations of Parts and Labor, icons for physical equipment and directional flows are chosen from menu forms. The display is updated as you proceed so that mistakes can be corrected immediately. There is a graphical screen editor that enables you to draw text, shapes, lines and icons that are not related to any specific element.

You can edit the icons so that they look like the equipment or Parts that they represent and save them for use in other models. These icons can be specified to change color according to their current status. You can display a set of legends describing the meaning of the status color codes.

4. THE DETAIL PHASE

In the Detail phase, logic is built into your model. Each element has a pre-defined form or template which you must fill in to specify its behavior. This will include information such as cycle times, Labor requirements, speeds, capacities and breakdown patterns. You fill in the blanks as the form prompts you for information and checks the validity of your answers.

Information can be specified as a constant value or as a compound expression or sample from a distribution. In this way, you can make operations dependent on Part types, the status of other equipment or random occurrences.

In addition to the standard fields, you can specify Actions or commands that will occur when an element changes its status. This is a powerful way of including the intricacies of a particular process and is explained in more detail in a later section.

4.1 Input and Output Rules

The flow of Parts, Fluids and Vehicles through the model is controlled by joining physical elements using Input and Output rules. You specify where each physical element will get Parts and Fluids from and where it will send them next. The rules can be simple "always" rules or the routing may be made dependent on Part, Fluid or Vehicle types or the status of other elements.

If the elements to which you are trying to send the Part, Fluid or Vehicle are busy or full, the element will become Blocked and will wait until the time at which movement can occur. Similarly, if nothing is available to enter an element, it will become Idle. Elements may wait until Parts and Fluids are sent to them or may pull on demand. In this way, you can model either pull or push systems or a combination of the two with the following rules:

Wait - To wait until Parts, Vehicles or Fluids are delivered or removed by another element.

Push - To send Parts or Vehicles to a specified element or elements in priority order.

Pull - To obtain Parts from a specified element or elements in priority order.

Most - To choose the element with the most Parts or free capacity from a list of elements.

Least - To choose the element with the least Parts or free capacity from a list of elements.

Percent - To choose from a list of elements according to their relative probabilities of selection.

Sequence - To choose from a list of elements in order. You may specify whether to wait, try the next element or restart the sequence if it cannot be maintained.

Select - To choose from a list of elements according to the value of an Integer expression.

Destination - To route a Vehicle according to its ultimate destination.

Flow - To send Fluids to one or more elements at the rate specified.

Connect - To establish flows between a pipe and another element at the flow rate of the pipe.

In addition, all the above rules, except for Sequence and Percent, may be used with IF, ELSEIF and ELSE statements to specify that a rule should only be executed when certain conditions are true. The exceptions above cannot be used conditionally, as the result could be ambiguous.

Sources and destinations can be any physical element or one of several special names. These names include WORLD, to pull Parts or Fluids on demand, and SHIP and SCRAP to push Parts or Fluids out of the model. Parts can be sent to ROUTE to make them proceed to the next location in their operation sequence, or you may specify that Parts go to, or are obtained from, different locations according to type.

4.2 Actions

Actions are commands that can be specified when an element changes status or a Part or Vehicle moves from one location to another. The format for using actions is similar to that of a simple programming language. Commands can include changing the values of Variables and Attributes, reading and writing data to and from Files, summoning a Vehicle to load Parts or recording information in a Timeseries.

Actions provide a way to replicate detailed process control logic. Editing actions is via a full screen editor that checks the syntax of commands and immediately translates them to low level instructions for fast execution without compilation delays.

4.3 System Functions

WITNESS has numerous in-built functions that will return the status or performance of an element or make a sample from a standard distribution. These may be used to determine routing choices and priorities. A list of these functions and their parameters is available through the Help menu option.

Status functions will return the condition of elements. These include the number of Parts in an element, the amount of Labor currently available, the next destination of a Vehicle and the current flow through a Pipe.

Performance functions return information about how an element has operated in the current model run. These include the percentage of time spent setting up, the number of a specific Part type that has been scrapped, the amount of Fluid that has been mixed and the maximum value recorded on a Timeseries.

Sampling functions will provide a random sample from a standard distribution. Available functions include the Normal, Negative Exponential, Uniform, Triangular, Weibull, Gamma, Beta, Binomial, Poisson, Erlang and Truncated Normal distributions.

5. THE RUN PHASE

In the Run phase, your WITNESS model is executed. Model building with WITNESS is fully interactive, ie. at any point in developing or using a model you may define new elements or modify existing ones. Having made the changes you can continue running the model from that point in time.

The Run commands in WITNESS are designed to take advantage of this feature so that you can build, validate and use your model without unnecessary delays. Models may be run graphically or in Batch modes and a Step facility is available to display a record of status changes which may also be written to a Trace file as a debugging aid.

A further important debugging aid is the ability to save the status of the model to disk. You can restore the saved status at any time to investigate a logic problem or show an unexpected phenomenon to an audience. Finally, you can run models from a WITNESS Command File that replaces keyboard input enabling you to automate the testing and experimentation process.

WITNESS encourages you to build a model in stages, testing each as you go along. The next section explains several of the other interactions that help you to build accurate models and test the validity of each section.

5.1 Interactions

Graphical simulation shows obvious errors in the construction of a model, but to fully test the validity of your model, often you need to perform more detailed analysis. WITNESS has the following interactions to help you do this :

Reports - Statistics for each element in the model are collected automatically. The Reports menu option will let you view statistics for selected elements. These statistics also may be printed or saved to ASCII or DIF format files. There is an option to reset statistics after a warm-up period and statistics may be output to file at regular time intervals.

Explode - To display a report of the status of each element and the Attributes of each Part in the model.

Used - To provide cross-reference information about the way in which elements are related.

Events - To display lists of future scheduled events, idle and blocked elements and elements that are waiting for Labor to become available.

Summary - To view the main details of each element type in tabular format.

The options above, when used with the Step and Save Status interactions, make it easy to diagnose logical errors in a model. The ability to change element Details at any time lets you correct mistakes as soon as you find them.

6. CONCLUSION

WITNESS is a menu driven, graphical simulation system for modeling manufacturing operations. It has been designed to enable people with no previous simulation experience to learn and apply simulation modeling quickly.

Models are constructed by defining the key elements that make up the manufacturing system, displaying them on the screen and specifying the details of their timings, routings, capacities, labor requirements, etc.. The latter information is entered on a Detail form or template that prompts for relevant information and checks the validity of each answer. Complex routing and control logic is achieved with Input and Output rules and with Actions commands on change of element status. Many interactions are available to help you validate and experiment with the model. Any desired changes can be incorporated instantly without code compilation or the need to reset the simulation to its initial state. All this makes WITNESS a unique combination of ease of use and power and flexibility.