AN INTRODUCTION TO QUEST

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ABSTRACT

This paper describes QUEST, a true 3D discrete event simulation package that is designed for simulating manufacturing processes. QUEST is used as a tool in ensuring cost-effective process design, identifying and understanding process problems and in evaluating proposals for changes to processes.

The objective of this paper is for the reader to obtain a basic understanding as to how QUEST is used to build models and how the models are used to identify and solve problems.

1 2D AND 3D MODELING 'WORLDS'

QUEST allows the user to select between building models in a 2D or 3D 'world'.

The 2D world is typically used for rough cut modeling, where the physical layout of the facility is not considered to be important. For example, the conceptual level design of a manufacturing process does not usually include the lengths of conveyors; as it may be inappropriate to try and include such details at an early stage of process design.
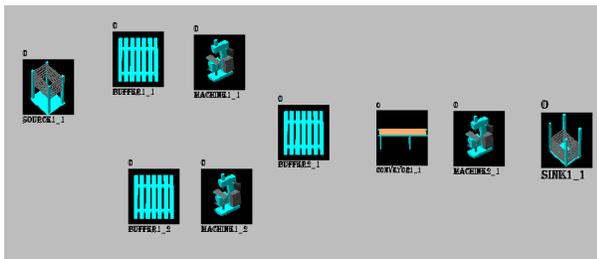

Figure 1: 2D Rough Cut Model

In the 3D world, the modeling is based on accurate 3D geometries. This level of detail is required as the process design becomes more firm and clear and accurate performance measures are needed. At this stage the length and location of conveyors and other material handling equipment and the distance walked by people is likely to have a critical effect on the overall process performance.
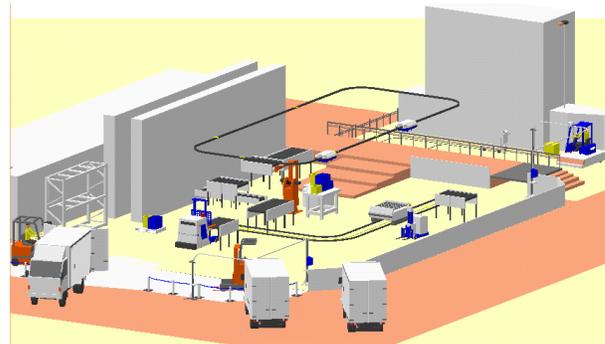

Figure 2: 3D Model

QUEST allows models to be transferred from the 2D world into the 3D world. In this way, the model can start off at a simple conceptual level of detail and then evolve as the design process progresses. This approach avoids the requirement for two different models being created on different software.

QUEST provides an extensive library of 2D and 3D geometries enabling the user to simply select an existing geometry to represent resources and parts.
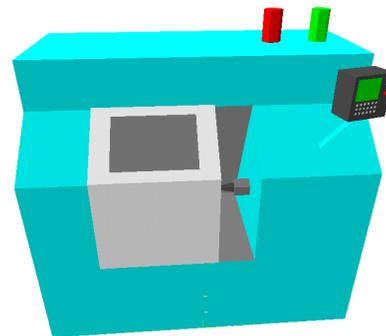

Figure 3: NC Machine

QUEST also provides complete CAD capability to create and modify geometries or to import geometries from a wide range of CAD packages. Note that 2D and 3D geometries can be saved and used in different models.

2 USER INTERFACE

QUEST's user interface enables building and running of models. It is very powerful and allows quite complex models to be built without the need for programming. As an overview, the user interface is used to create model elements, describe their behavior, run the simulation, review results and perform 'what if' simulation experiments.

2.1 Classes and Elements

Building a model through the interface consists of creating elements (e.g., conveyor XYZ), locating them in the model world (by point and click or by specifying coordinates), and then providing details on the elements' behavior (location, length, speed, etc.).

   Each element is created within an element class of similar elements (e.g., conveyors with the same characteristics as conveyor XYZ). When elements are created they are located in the 3D world either by point-and-click location or by specifying the coordinates.

   Each element class has a set of detailed data (parameters) that control the look (geometry) and behavior of its elements. An individual element may also have its own behavioral characteristics. Data is typed into a dialog box or selected as an option.
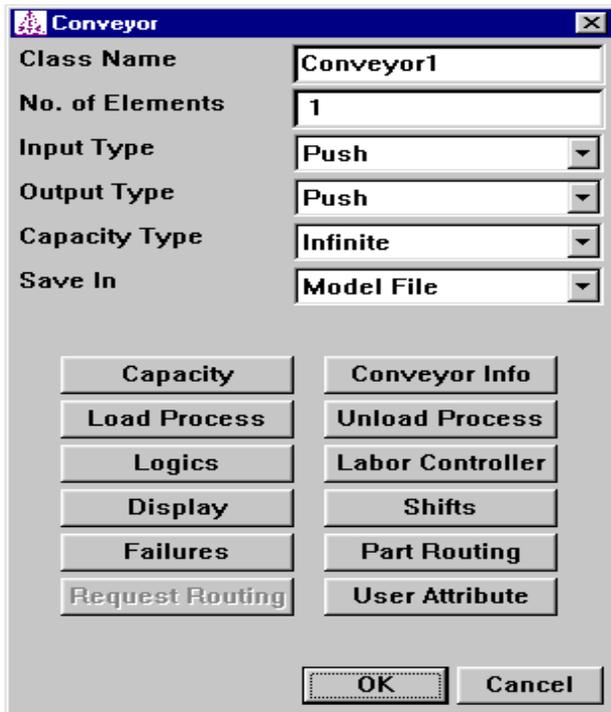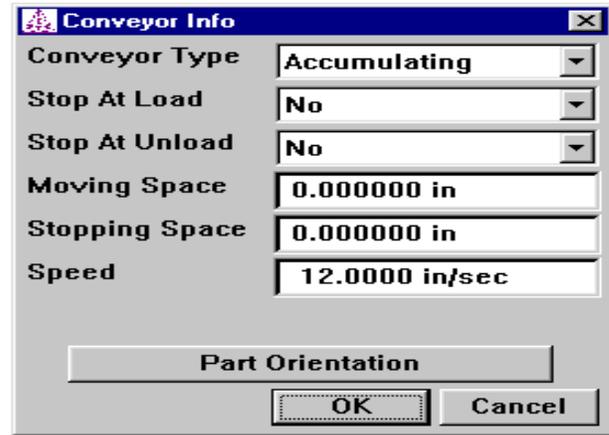
Figure 4: Element Class Dialog Box

Figure 5: Element Class Details

   The scope of the dialog boxes allows quite complex models to be built entirely within the user interface. Note that any element class can be saved as an independent object and can be reused in different models.

2.2 Element Class Types

QUEST provides a powerful range of element classes that include:

Accessories	- geometries for improving the realism of the model
AGV	- transporter e.g. fork lift, automated guided vehicle, crane
Buffer	- storage of parts
Conveyor	- continuous linear parts movement
Failure/Repair	- failure/repair patterns
Labor	- labor moves parts, works on machines
Machine	- processing of parts/assemblies
Part	- parts, tools, fixtures
Power and Free	- fixed interval carrier-based transportation
Process	- details of loading, unloading or part/assembly processing
Sink	- removal of parts
Source	- generation of parts

2.3 Part Flow

Routes for parts flow are created in two stages. First, possible part flows are created by selecting 'from' and 'to' elements. This is done quite simply through point-and-click methods. Second, control rules are specified to govern part flows under various circumstances. Control rules may be selected from an existing library and applied to either class or element levels.
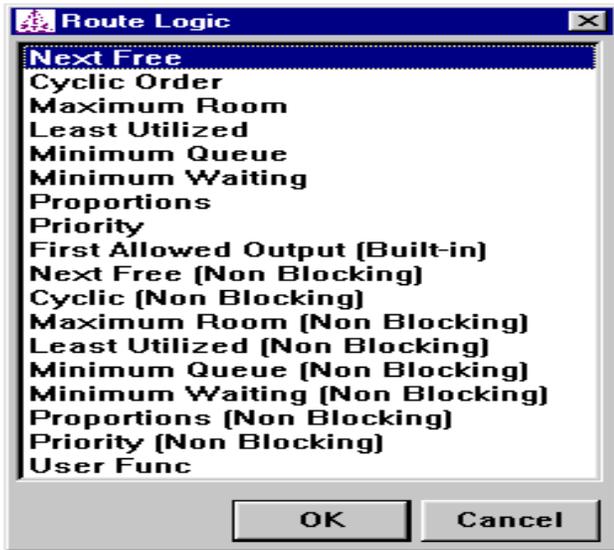
Figure 6: Part Routing Rules

3 OBSERVING THE SIMULATION RUN

While a QUEST simulation is running, the user has complete interactive control to zoom in and fly through to examine model behavior. This observation can be done with Virtual Reality devices such as stereo glasses, or full immersion devices. Realistic 3D simulation can be a very effective medium for communicating to observers from various disciplines.

By now, the value of graphics in communication is well established in discrete event simulation. However, the ability to relate to conceptual 2D iconic representations is not general. The use of high level graphics, texture maps, virtual reality makes it easy to understand what the simulation represents. QUEST extends this capability via Virtual Collaborative Engineering (VCE). VCE enables observers, who are located in different parts of the world, to view and interact with the 3D simulation, connected by a normal telephone line.

QUEST's animation should be distinguished from a 3D fly through of static 3D 'models', 3D animations which have no simulation base and from post-process animations of simulations. In QUEST, as the simulation is running, the true behavior of the facility is being animated and displayed. The observers can not only 'walk' or 'fly' around the running simulation, but they can modify parameters or examine performance statistics of the model.

4 SIMULATION RESULTS

Performance statistics can be displayed or sent to file for use by other software packages (e.g., including in a report). There is a wide range of standard reports available and customized reports can be easily created. The following are just a few examples:

- At the overall model level there is a table of statistics, including overall throughput and the maximum utilized resource.

Figure 7: Model Summary Statistics

- For each element, various statistics may be displayed on individual tables such as the throughput, busy, idle and repair times.

Figure 8: Element Statistics

- Statistics can also be displayed in graphical form and continuously updated as the simulation is running.
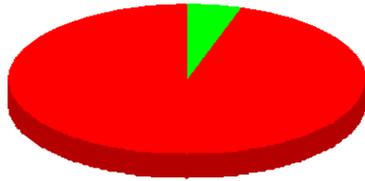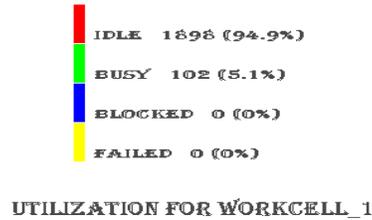

Figure 9: Pie Chart

Performance statistics can be shown using pie charts, bar charts and time plots. These graphs will show the statistics changing as the model is running, allowing the user to observe the effects of behavior on performance. There is a wide range of standard graphs and customized graphs can be produced.

5 EXPERIMENTATION

By running the simulation several times with some changes, or with randomness, different behaviors can be examined and compared.   QUEST automatically captures results for each simulation run and allows the user to select and examine the comparative performance statistics across the different runs.

Figure 10: Confidence Interval Across Runs

6 SIMULATION CONTROL LANGUAGE (SCL)

All elements in QUEST are controlled by a set of behavioral rules that can be selected by the user from a list of alternatives displayed in the user interface. Each behavioral rule is a simulation program that is written in QUEST's Simulation Control Language (SCL). SCL code is provided for each standard behavioral rule. The user can modify or rewrite a selected rule and can even add new rules to the user interface.   This open architecture allows the user to control model behavior at a very detailed level.   In most cases, provided SCL behavioral rules are sufficient. However, modifications can be made where ever necessary.

SCL is extensive and powerful in order to meet the unique needs of complex models. It is object-based in that each element class has its own SCL programs that control the behavior of the elements in the class. Features of SCL include:

- Access to model state information
- Event control
- File input and output
- Full-featured on-line debugging
- On-line documentation
- Socket communication with C programs
- Standard text handling, mathematical routines
- Structured programming
- Variable types, including dynamic lists and structures

Note that modified or new programs can be saved for use in other models.

7 BATCH CONTROL LANGUAGE (BCL)

QUEST models can be run several times through the user interface. However, the user may want to specify a series of simulation runs for experiments. Typically, BLC is used to create a series of runs with alternative scenarios without user intervention.

BCL has been developed beyond the run control stage. Now, advanced users can drive QUEST modeling and simulation run control from other custom-built user interfaces.

For example, a company that has a central expert simulation group may want to provide simulation capability to other engineers, and reduce their learning curve and the modeling time.   By creating a user interface in a toolkit such as Visual Basic™, the central function can provide their users with an interface that is geared specifically to their facilities and terminology.

8   THE VIRTUAL FACTORY

QUEST is one of a suite of integrated simulation products that together provide the capability to produce a virtual factory simulation. Each product, including QUEST, can operate entirely stand-alone.   However, together they provide a worldwide collaborative engineering simulation capability.

   The products include:

- IGRIP – simulation and off-line programming for robots
- UltraArc – simulation and off-line programming for arc weld robots
- UltraSpot – simulation and off-line programming for spot weld robots
- ERGO – simulation of human movement, including posture analysis and energy expenditure analysis
- VNC – simulation of NC machinery, including verification of NC code
- UltraGrip – simulation and off-line programming for water jet cutting robots
- Envision – virtual prototyping, including assembly simulation and ergonomic simulation
- UltraPaint-simulation and off-line programming for painting robots
- Assembly-dynamically prove out assembly and maintenance task feasibility

   Each of these simulation products operate at what might be termed a 'workcell' level. Workcell simulation is highly detailed, involving such features as collision detection and inverse kinematics.

   QUEST can integrate these detailed simulation models into a single process simulation. This permits engineers from different disciplines to see the impact of their workcell on the overall process. The integration permits the user to instantly access the detailed workcell simulation.   This provides the capability to utilize lessons learned at the process level in the design and operation of workcells and vice-versa.   This collaborative engineering capability, combined with VCE (previously mentioned), facilitates a multi-disciplinary team of engineers, who may be geographically remote, to function effectively towards a common goal.

9   ADDITIONAL FEATURES

QUEST has a wide range of features, including:

- Access to data to/from spreadsheets
- AVI, JPEG, MPEG and TIFF output
- Kinematics

- Access to process information from MRP or other process planning system
- Schedule-based input from MRP, or other scheduling system
- Shifts, setups, loading/unloading times
- Sub-model storage and retrieval
- Video output

REFERENCES

QUEST User Manual Ver. 4, 1997, Deneb Robotics Inc.
SCL Reference Manual, 1997, Deneb Robotics Inc.
BCL Reference Manual, 1997, Deneb Robotics Inc.

AUTHOR BIOGRAPHY

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