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INCREASING THE POWER AND VALUE OF MANUFACTURING SIMULATION VIA COLLABORATION WITH OTHER ANALYTICAL TOOLS: A PANEL DISCUSSION

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ABSTRACT

The objective of this panel session is to describe how and when manufacturing simulation practitioners should add to the value of projects by interfacing simulation analyses with other analyses such as optimization, layout/material flow, scheduling, robotic, and queuing. The panelists will discuss how each analytical tool adds value to the discrete-event manufacturing simulation, when in the life cycle of a project it should be brought in, what are the main advantages and disadvantages of bringing in the additional tools, managing and selling collaborative analyses projects, and training requirements for collaborative analyses.

1 MANUFACTURING SIMULATION AND OPTIMIZATION (GENE COFFMAN, FORD MOTOR COMPANY)

Often, when developing the objectives for a simulation project, one is asked by the customer to answer questions of the form: What is the best buffer configuration? What is the lowest cost solution that meets the minimum requirements of the system? How many AGV or Material Handling devices are needed? Clearly these types of questions lead one to think "optimization" tool. Traditionally however, the answers are obtained in a simulation study during the experimentation phase using an ad hoc design of experiments (DOE) approach, followed by a binary search "near" the best DOE solution. In many cases it may be possible to use an optimization tool to guide the search for the best solution.

There are three main disadvantages when using optimization tools with simulation models: statistical variability, model complexity, and run time. Most simulation models contain one or more sources of randomness, otherwise, a different tool (e.g. Spreadsheets) would most likely provide a more effective modeling environment for the problem. This naturally leads to variation in the output and hence, the evaluation of the objective function of the linked optimization problem. This variability can cause an optimization algorithm to be "mislead" or even fail. Multiple replications and variance reduction techniques can reduce the potential effects, but never totally eliminate it from being an issue. In general, the traditional algorithms must be modified to account for this possibility.

There are several dimensions to the model complexity issue. One is that more complex models tend to take a significant amount of CPU time to run (minutes, hours or even days). The implications of long run times are discussed below. A second dimension is that complex models may "lock-up" or fail to complete under certain combinations of input parameters. Depending on the definition of the objective function and the affect on output statistics, this failing combination could appear to be a very "good" (or very "bad") solution to the algorithm.

The solution time of optimization problems in general are related to several factors including: number of variables, types of variables (discrete or continuous), number of constraints on the solution space, type of constraints (simple bounds, linear, or non-linear), and type of objective function (linear, quadratic, or non-linear). Furthermore, when using an optimization tool with simulation, the time required to run the simulation model to obtain statistically significant results becomes an important factor since this becomes the time required to perform an objective function evaluation. (The above factors indicate how many times the objective function needs to be evaluated to arrive at an "optimal" solution.) In general, simulation models tend to contain both discrete and continuous variables and constraints that are often non-linear (or even non-differentiable). Because of this complexity, algorithms that do not depend on derivative information are required. (i.e., genetic algorithm, simulated annealing, etc.) These algorithms tend to require even more function evaluations. For example, if a given simulation model requires 5 min. to execute a single run and requires 5 replications for statistical significance, then each function evaluation requires 25 min. Thus, if it takes 1000 function evaluations to reach a near-optimal solution, it would take over 17 days to process.

If used with care, an optimization tool can provide the user with benefits. For example, the optimization tools could be used as a method of automating and improving the DOE experimentation process. Some of the algorithms linked with existing simulation tools provide a limited capability to do this (e.g., full factorial). In addition, the optimization tools can improve experiment time by taking short-cuts and eliminating experiments with little impact on the objective. Another benefit of an optimization tool is in the exploration of areas of the feasible solution space not included in traditional DOE.

The use of optimization tools should be approached with caution. However, when combined with traditional DOE analysis, it can be used very effectively to obtain improved solutions or better system configurations. User training is critical to success by helping the user avoid some of the pitfalls identified above and to understand the impact of any short-cuts taken to try to speed up the process. Basic understanding of statistical variability and the underlying assumptions of particular optimization algorithms available must be a significant part of a user's training.

2 SIMULATION BASED ADVANCED PLANNING AND SCHEDULING (MATT ROHRER, AUTOSIMULATIONS)

Simulation Based Advanced Planning and Scheduling (APS) is a technology that allows manufacturers to determine the number of resources they'll need (Planning), and what those resources should work on next (scheduling). AutoSimulations offers a suite of software tools for planning scheduling, and analysis, called the AutoSimulations Productivity Family (APF).

APS tools based on simulation can give an accurate picture of how a factory will operate given a specified equipment set, product mix, and loading. Inputs to the model include number of types of machines and operators, shift and downtime schedules, product routing and setup requirements, and customer orders to be completed.

Outputs from a scheduling model include the utilization of equipment and storage areas, throughput and cycle time, and ability to meet due dates on customer orders. APS models help planners and schedulers do their jobs better by providing an accurate representation of the actual facility. Because most production systems are vital to company success, and shouldn't be interrupted, experimentation with the actual system is not possible. APS models allow operations personnel to better understand their manufacturing operation, helping them get the most our of their resources.

User's of APS technology are able to reduce cycle time and achieve higher levels of throughput without purchasing new equipment or having their operators work more hours. By simply changing the sequencing discipline, higher throughput can be realized. We have seen this result in several industries, including semiconductor manufacturing, book binding, and steel production.

APS requires an extensive amount of data about the manufacturing operation. That is why most good APS systems, including AutoSimulation's APF, have real time links to the manufacturing execution system. Without accurate data that represents the current state of operations, APS cannot provide the value required.

Where discrete event simulation is used in the design and analysis of manufacturing systems, APS is used in the long-range operations planning and short interval scheduling of the facility. This means that APS tools can be used to determine what each piece of equipment should do tomorrow, next week, and next month. The disadvantages of APS include:

- Data requirements – need a lot of data to be useful
- Effort to build an accurate model – sometimes representing decision making logic can be difficult
- Run time performance – with large, sophisticated APS models, run time can be an

issue. You have to get results from the model in order to do useful work with it.

APS is typically sold to production planners and schedulers to help them perform their job more quickly and with greater accuracy. Because of the data requirements, Information Systems personnel usually get involved as well. APS model users can be anyone who understands the operation being modeled and who can interpret the results. Usually it takes a few hours to a few days to train an APS model user.

APS model builders have to understand the APS tool being used and its world view. They also have to quickly acquire knowledge of the system to be modeled, and must have an aptitude for translating the system description into a working, accurate model. APS model builders need months or even years of experience to become proficient at representing manufacturing systems in the computer. The more challenging aspects of APS model building include:

- Scheduling rule development
- Integration with existing information systems
- Verification and validation of the model

APS tools can be extremely beneficial in helping companies squeeze more out of less. Years of experience running a facility can be acquired in just a few hours of experimenting with an accurate APS model. Additionally, production personnel can be convinced of a "different way" of operating using an APS model to describe the effects of change.

3 ROBOTIC SIMULATION (JOHN SHORE, PRODUCTION MODELING CORPORATION)

Robotic simulation software is a 3-D graphical simulation package that is used to simulate industrial robots, work cells, and kinematic systems. This provides engineering concept analysis and layout design prior to purchase and installation, helping to detect collisions and other spatial interactions, and to analyze and optimize cycle times, placement, control sequence, mechanical motion, in the integration of components. Off-line programming is another important use of robotic simulation.

Robotic simulation is a kinematic simulation tool that contains unique attributes not found in many other simulation tools. Its primary use is as a highly detailed, cell-level validation tool. Most engineers use robotic simulation to verify robotic cell process operations. In particular, the tool can be used to "mock" up a station that contains robots or machines to check different parameters like: cycle times, object collisions, cell layout, and location of entities in the cell with respect to each other.

Robotic simulation adds value to analysis in several ways. First, it provides a highly detailed visual layout of an area in three-dimensional space. This allows users to visually see the environment in which their equipment will operate. This can be useful for demonstration purposes and for checking layout. Second, it provides a way to prevent collisions between entities in a cell. Most robotic simulation applications come with collision detection capability. It has the ability to demonstrate if two objects are going to collide with each other. Third, robotic simulation is a useful tool for checking cycle times of a cell. These programs can be used to verify; for example, how long a robot will take to complete its task. The programs can also help the user determine if a shorter path is available to reduce a robot cycle time. Most of these simulation packages are equipped with optimization algorithms that can help the programmer to find the quickest path for the robot to take in reaching its destination. Lastly, robotic simulation packages have the unique ability to allow the user to convert the actual simulated model into robotic programming language. This gives the engineer the advantage of utilizing the entire lesson learned from the simulation and downloading it straight into the robot that will be used on the plant floor.

Robotic simulation is used in all phases of manufacturing. It can be used in pre-production planning or during production. However, it is most useful in the pre-production planning phase of manufacturing assembly. In this phase, many alternatives can be tried with very low cost and without impacting operations. The more time spent in the initial phases designing a work cell using the robotic simulation packages, the more money that will be saved in the future by the end user (i.e. the plant).

These tools are very helpful in identifying problems up front such as possible collisions, stations that are over-cycle, and layout obstacles that ordinarily would not surface until after production has already began. The cost to run the alternatives is miniscule with respect to the cost if those same changes had to be made at the time of production.

Robotic simulation is different from traditional discrete event simulation in several ways. First, robotic simulation is much more detailed. It is a "micro" analysis tool where the emphasis is to look at the detailed workstation or cell-level area of a production facility. Discrete event simulation packages, however, can look at a "macro" and "micro" level issues. Discrete event simulation can be used to look at problems on an enterprise scale as well as a station cell scale. Depending on the issue, if a larger scope is needed in a user's analysis they may have to look at discrete event simulation to help them solve their problem. Second, robotic simulation packages are "static" in nature compared to their discrete event counterparts. Discrete event packages have the advantage of incorporating random events in the modeling of a system. Discrete event simulation packages incorporate pseudo random number generators and numeric distributions in their software that can demonstrate the impact that variability will have on a system. Robotic simulation packages can not do this. Third, as mentioned before robotic packages have collision detection capabilities that are not necessarily incorporated in most discrete event simulation packages. In fact, most of the discrete event simulation packages do not even have true three-dimensional visual modeling capability. Lastly, robotic packages also have the capability of translating the robotic movement in a model into code for an actual robot on the floor.

4 LAYOUT/MATERIAL FLOW (DAVE SLY, ENGINEERING ANIMATION, INC.)

What are the main characteristics of the collaborative tool/ analysis technique? How does the tool add value to the simulation analysis? Which applications does it fit well?

Our collaborative tool is the layout to simulation interface called SDX (Simulation Data Exchange). The main function of the tool is to communicate to the simulation package, all that is known about the layout in an effort to reduce the redundant tasks of redefining equipment in the layout importation to the simulation tool and that equipment's inter-connectivity and attributes. This interface adds value in that it can cut considerable time from the process of creating detailed layouts in the simulation tool and defining equipment properties (such as conveyor speeds, etc.). The interface is best applied to applications that have a significant amount of automated material handling equipment such as conveyors, agvs, fork trucks and cranes, all typically found in automotive plants and distribution centers.

When in the life-cycle of a project the collaborative tool should be brought in (before, after, or concurrently with the simulation study)? How does it interface (data, etc.) with the simulation analysis?

This interface is typically used throughout the entire facility design process and not typically used after the facility is built. Current models that have been brought into the simulation package from FactoryCAD via the SDX interface confirm that between 25% and 100% of the simulation model can be automatically defined.

What are the main advantages and disadvantages of the collaborative tool/analysis technique? How does it complement the simulation analysis?

The main advantage of this tool is that it reduces the effort of building simulation models while simultaneously improving the quality of those models. SDX requires that the user use FactoryCAD with AutoCAD in order to create their plant layouts which will simultaneously improve the quality and ease of creating those layouts.

How should we manage and sell (internal/external) the collaborative analysis projects? What are the training requirements for such projects (background required, etc.)?

Not much selling needs to be done. Most everyone already uses AutoCAD for their plant layouts, therefore, by simply adding FactoryCAD to speed up their layout creation process they will be able to save their layouts in the SDX format for automatic importation into the simulation environment. Training to use the interface is minimal (a few hours to one day).

5 QUEUEING ANALYSIS (DEMET WOOD, GENERAL MOTORS)

What are the main characteristics of the collaborative tool/ analysis technique? How does the tool add value to the simulation analysis? Which applications does it fit well?

Queueing Theory studies systems where there are a number of service nodes for entities with known arrival rates and entities form a "queue" before these nodes. Queueing theory provides exact or approximate answers for such systems under specific assumptions. For example, it provides very accurate results for straight-line systems with exponential distributions. As the system under study gets more complicated and non-exponential distributions are involved, more restrictions arise. Some of the typical restrictions are number of nodes, number of diverge and converge points, number of loops, and the use of non-exponential distributions.

Because queueing theory-based tools are analytical by nature, their results tend to be faster than simulation. Therefore they can be used as a precursor to simulation to answer some of the easy questions or to limit the problem space. An effective use of these tools can decrease the number of "what-if" questions that need to be answered with simulation.

Such tools are useful for applications where the system can be modeled as a queueuing system. Typical applications are manufacturing, service and distribution systems. GM uses a proprietary queueing-based tool for all manufacturing applications. It is used to compare designs, find bottlenecks, and identify the best places for buffers (queues).

When in the life-cycle of a project should the collaborate tool be brought in (before, after, or concurrently with the simulation study)? How much interface (data, etc.) does it have with the simulation analysis?

Queueing theory based tools are most useful if used before the detailed simulation analysis. This helps to decrease the problem space by eliminating some of the alternatives, it also helps the direction of the study by ranking and providing boundries for the alternatives. However they can also be used concurrently to analyze alternatives that arise during a project.

All the data used for queueing theory based tools are also used by simulation; arrival and service rates, queue sizes, etc. However, simulation may require additional data and/or information, such as, complicated divergence rules, merge rules, specific queue ranking rules, empirical distributions, etc. Replication of data entry can be eliminated by using a common interface for both tools. Use of a common interface shortens the project time and also eliminates possible data entry errors.

What are the main advantages and disadvantages of the collaborative tool/analysis technique tool? How does it complement simulation analysis?

The main advantage of queueing theory based tools are their speed in comparison to simulation. However, they place many restrictions and assumptions on the system studied. Also, they may not be able to provide all of the statistics that simulation can. For example, these tools may be able find the output rate of a system, but utilization of the nodes may not be available. In addition, the tools may provide only approximate results, leaving room for inaccuracies. On the other hand, while using these tools the hard questions of simulation analysis do not exist; namely, the determination of the warm-up time, run-length, and the number of replications.

How should we manage and sell (internal/external) collaborative analysis projects? What are the training requirements for such projects (background required, etc.)?

Two of the main issues related to simulation projects can be easily solved by using Queueing Theory based tools: timing and customer confidence. Typically, simulation projects start with a lot of customer's "what if" questions. Some of these alternatives can be eliminated quickly by using the queueing theory tools or other analytical tools. Some of this analysis can even be done in front of the customer while the alternatives are being discussed. This both decreases the project time and increases the customer confidence in the analysis. Even when the analytical results are not exact but only approximate, they can be used for ranking the alternatives.

When using both tools, the shortcomings of each need to be clearly understood by the analyst. Both the analyst and the manager of the project should have a background on simulation, statistics and queueing theory. Special care needs to be taken when reporting to the customer to ensure that the customer understands the limitations of the results. Each tool may have a different answer for the same system: approximate results from the analytical tool and a confidence interval from simulation. Obviously, for a validated study both results should be correct and make sense to the analyst. Depending on the customer's background, you may choose to publish both results and explain them or publish the one that is more understandable by the customer.

AUTHOR BIOGRAPHIES

MATT ROHRER, Vice President of Simulation, joined AutoSimulations, Inc. in 1988. Over the past 11 years, Mr. Rohrer has been a simulation analyst, has managed the AutoSimulations Consulting Group, and has guided the development of AutoMod. He has been active in the simulation community during his career. Mr. Rohrer wrote a chapter in the Handbook of Simulation edited by Dr. Jerry Banks.

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