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SIMULATION INSTRUCTION -- CORPORATE VS. CAMPUS

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ABSTRACT

Ford Motor Company has developed a triplet of in-house simulation classes: an overview of simulation in manufacturing, an introduction to simulation methods, and language-specific classes in SIMAN and WITNESS. This set of courses is described and, as an example, the in-house short-course training of engineers and vendor-partners' engineers in simulation methodology and the use of SIMAN is compared to and contrasted with a typical university semester-length course in simulation, its methodology, and its software.

1 INTRODUCTION

Ford Motor Company, wishing to further exploit the ability of simulation to improve the efficiency and cost-effectiveness of facilities-and-tooling [F&T] design and development processes, has developed a unique approach to teaching classes in simulation methodology. These classes are attended jointly by Ford process engineers and by the design engineers from vendors responsible for design of F&T systems for production of future vehicles.

Classes using either SIMAN or WITNESS are offered.

2 OVERVIEW OF FORD'S IN-HOUSE CLASSES

2.1 Class Outline

A typical class runs two, two and a half, or three days, depending on the attendees' time available and prior experience, if any, with simulation technology. Although each class is customized for the participants, the basic outline contains:

I Ford's simulation methodology: the nine steps
1. Identify opportunity
2. Define objectives and scope of study
3. Collect data (including operational strategy)
4. Build model
5. Verify and validate model
6. Experiment with the model.
7. Analyze results.
8. Approve and implement changes to system.
9. Document the model and its results for further use.

II Introduction to a simulation tool (SIMAN or WITNESS)

experimentation using the tool
fundamental modeling constructs (e.g., entity creation, queueing, use of resources)
adding randomness to a model
fundamental statistics-gathering
modeling of stations
modeling of transporters and conveyors

Basic model-building exercises

Statistical analysis and statistical tools

Student-defined exercises -- modeling a subset of the F&T system under design

2.2 Class Objectives

The primary class objective is to place the tool in the hands of engineers. These classes enable them to become knowledgeable users of simulation and customers of simulation services. Our objective is not to build the model, but rather to provide the manufacturing engineers with a tool -- simulation -- for prototyping the proposed system during its design and development. Ford and the F&T vendor may jointly decide to contract the actual model-building effort to a third-party specialist in simulation services. Class attendance prepares both Ford and F&T supplier engineers to choose and use such services to best advantage. The class also identifies some of the pitfalls of simulation, such as absence of a clearly defined objective, failure to document continually and thoroughly, neglect of reporting interim progress and successes to management, or adding too much complexity to a model too soon. The checklist of pitfalls thus provided has proved itself an effective problem-avoidance precaution, just as is an airline pilot's checklist.

Additional objectives are:

-- Establish interface between Ford engineers and vendor engineers, so that the simulation model will be built from, and its analysis undertaken from, a common perspective. Such a common perspective greatly enhances the long-term value of models built later, enabling them to become "living documents" throughout the life of the manufacturing process being simulated. Benefits of having Ford engineers and F&T suppliers' engineers in the same classes include:

- improved communication between Ford and its suppliers, in keeping with current managerial goals of forming long-term relationships with a core of carefully selected, trusted suppliers
- explicit opportunity to stress the importance of modeling and validation of F&T suppliers' design proposals
- reduction of the time Ford engineers need to consult with the supplier on the input data and the results of simulation analyses subsequently
- insurance that models are built according to Ford's guidelines, enabling a Ford engineer to use the models to assess future enhancements efficiently

The class does not prepare attendees to become expert model builders; however, it can lay the groundwork for the future training required by an engineer later needing that expertise.

2.3 Typical Background of Engineers Enrolled

Engineers enrolled in these classes are typically plant, process, or industrial engineers with little or no prior simulation experience or training. Although most of the students have some proficiency with a computer, they earned their university degrees in a major not requiring simulation, or earned them before classes in simulation became common. Whereas today's university student enrolled in a simulation course has typically studied statistics within the previous six to twelve months, statistics study and usage for our students may be farther in the past. Accordingly, when we present Ford's simulation methodology, we stress the importance of statistical analyses of both input and output of the simulation analysis. Further, we review, and provide references for, fundamental statistical concepts and methods as needed. We also mention, and recommend engineers enroll in, Ford's internally offered statistics classes.

On the other hand, our students are vastly more experienced in day-to-day production, problem-solving, and troubleshooting than most university students, even those who have had internships in the automotive industry. As one example of these differences, a university student typically solves simulation exercises containing givens such as "The downtime durations of machine X are lognormally distributed with parameters..." Contrariwise, we acknowledge forthrightly that no such given ever "fell into" a workaday simulation study gratis. (In our pie-chart of the nine steps of a simulation study, the slice labeled "Collect data" is much larger than the one labeled "Build model.") Hence, we emphasize the importance of data collection, the long-term value of collecting and archiving historical process data, the difficulties caused by the Hawthorne effect, and the value of statistical tools for fitting appropriate theoretical distributions to empirical data.

3 UNIVERSITY AND FORD SIMAN CLASSES COMPARED AND CONTRASTED

3.1 Commonalities of SIMAN Classes

Experience in teaching both university and in-house, shorter training classes using SIMAN has demonstrated the importance of stressing the following topics in both:

- The interplay between the model and the experiment frame. Each time we introduce a new modeling construct, such as counters or transporters, we mention the connection between the two. For example, on introducing the TALLY block, we note at once "In the experiment frame, there will be a corresponding TALLIES element."
- The ability of this model-experiment interface to help the modeler separate model logic from data, and hence to construct models easily updated by non-experts. As noted above, the most valuable models are often capable of being "living documents" during the lifetime of a process. The more numerical information is kept in the experiment frame (e.g., via the DISTRIBUTIONS and PARAMETERS elements), the more amenable the model will be

to routine updating as process parameters change.

- The distinction between an attribute (belonging to an entity) and a variable (belonging to the entire system). Students need to understand that changing an attribute value within one entity has no direct effect on any other entity, since the attribute has as many potentially distinct values as there are active entities, and to contrast that situation with the single-copy, single-value status of a system variable. By analogy, we ask students to visualize each entity as carrying its own attache case filled with numbers -- those are its attribute values.

- The importance of verification by tracing, and the helpfulness of the interactive debugger. Giving students an early tracing exercise helps them understand the fundamentals of the simulation clock, the distinction between "current" and "future" scheduled entity movement, and SIMAN's policy of moving an entity as far as possible at the current time before processing another entity.

- The contrast between observational and time-persistent statistics. We describe an observational statistic (such as "time spent in system") as a number tossed into a bowl of observations by an entity passing through a TALLY block. By contrast, we describe a time-persistent statistic (such as length of a queue) as internally maintained by SIMAN as a step-graph over time, whose significant values (e.g., average, maximum, minimum) are obtainable by DSTAT request.

- The hazard of unintentionally losing an entity by sending it to a QUEUE block, without balking provision, when that queue might already be at capacity.

- Entities must not "fall into" STATION blocks. Upon first seeing the concept of routine, the student typically finds it counterintuitive that a ROUTE block sends an entity to a STATION block immediately succeeding it. We explain the importance of the ROUTE block by noting that the value of attribute "M" is typically important within a station submodel, and that SIMAN will lose track of that value if the entity isn't routed properly.

- The need to set "NS" before using the "SEQ" method of STATION visitation; as we put it, assigning NS a value is instructing the entity "Follow this road map." Next, we explain "If you never set 'IS' (the most common situation), the entity will follow that map as listed. Skip-forward or retrace-steps will result from incrementing or decrementing IS -- do so cautiously."

- If an entity may have to wait before entering a block, it must have a QUEUE to live in while it waits. We thus explain the concept of hold-type blocks -- those which may temporarily deny entry to an entity. For example, noting which blocks must be preceded by queues helps distinguish sharply between the duties of a REQUEST block versus those of a TRANSPORT block.

3.2 Differences Between SIMAN Classes - University vs. In-House

Whereas a university course presents a broad, eclectic range of opportunities for simulation usage, such as those in the military, or the transportation and service industries, in-house classes can focus precisely on these engineers' key motivation -- the use of simulation to improve their manufacturing and production processes.

A university class heavily stresses details of how to use the simulation language as a tool, since the students will have to build term projects and write examinations based on knowledge of these details. On the other hand, we stress when to use the language as the modeling tool of choice. When our "alumni" begin to use the language, our ongoing help and in-house consultation will always be available.

Further, our students, unlike typical university students, have ample experience in process implementation -- bringing a process from drawing-board to factory-floor. Therefore, we stress the usefulness of simulation during all phases of a project, from design, through production start-up, and then during ongoing process improvement. For ease of making a model such a "living document," as described above, we outline the possibilities of equipping the model to receive its input from, or send its output to, spreadsheets easily updated and used by non-technical plant-floor personnel.

In university classes, we assign articles from simulation practice, such as application papers from Winter Simulation Conference proceedings. In Ford's in-house class, we not only do this, but also further motivate the students by showing them the actual code, conclusions, and benefits achieved by previous Ford simulation projects.

To emphasize the importance of the simulation-statistics interface, and to refresh our students' recollection of statistical concepts, we place strong emphasis on these topics. Examples of this emphasis include:

- mention of statistical packages in common use at Ford and appropriate for simulation input and output analysis

- more frequent commentary on statistical concepts, such as the significance of variability (i.e., is the 50 jobs-per-hour the result of {49, 50, 48, 53,...} or of {90, 12, 88, 10...}?)

- full demonstration of SIMAN's input processor capabilities to plot data, show the ability of various distributions to fit the data, and recommend a best-fit distribution

Ford class participants come already keenly interested in building a model of a proposed F&T design; hence, we use that as the analogue of a university class "term project." Our in-house class supplies one microcomputer per two students. The students work in pairs to model a subset of the F&T system for whose design they are responsible. This side-by-side classroom environment stresses, more than words alone could, the importance we attach to an team approach to model verification and validation throughout a co-operative model building and analysis effort.

Since the SIMAN capabilities for continuous simulation don't contribute to F&T system design, we omit that topic from our in-house class.

Likewise, since class time is strictly limited and FORTRAN-SIMAN interfaces are very rarely needed for our F&T simulations, we omit that topic also.

4 SUMMARY

Use of simulation methods and technology to build models of manufacturing systems enables Ford and its facilities-and-tooling vendors to work together toward common goals of high system productivity and quality coupled with early avoidance and correction of potential problems.

Classroom instruction, including "hands-on" model building by Ford and vendor engineers working together toward these goals, is a vital preamble to exploiting the powers of effective simulation modeling.

Side-by-side comparison of Ford's in-house SIMAN class with a university simulation class using SIMAN reveals significant differences, but even more fundamental similarities of purpose.

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APPENDIX: TRADEMARKS

SIMAN is a registered trademark of Systems Modeling Corporation.
WITNESS is a registered trademark of AT&T ISTEL Limited.

REFERENCES

Conrad, Sherri A., David T. Sturrock, and Jacob P. Poorte. 1992. Introduction to SIMAN/CINEMA. In *Proceedings of the 1992 Winter Simulation Conference*, ed. James J. Swain, David Goldsman, Robert C. Crain, and James R. Wilson, 377-379. Systems Modeling Corporation, Sewickley, Pennsylvania.

Law, A. M. and W. D. Kelton. 1991. *Simulation Modeling and Analysis*, 2d ed. New York: McGraw-Hill.

Musselman, Kenneth J. 1992. Conducting a Successful Simulation Project. In *Proceedings of the 1992 Winter Simulation Conference*, ed. James J. Swain, David Goldsman, Robert C. Crain, and James R. Wilson, 115-121. Pritsker Corporation, West Lafayette, Indiana.

Pegden, C. D., R. E. Shannon, and R. P. Sadowski. 1990. *Introduction to Simulation Using SIMAN*. New York: McGraw-Hill.

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