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SIMULATION EXPERIMENTER: AN EXPERT SUPPORT SYSTEM TO SIMULATION EXPERIMENT DESIGN AND ANALYSIS

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ABSTRACT

Most manufacturing systems nowadays operate under resource constraints. Resources must be used within an organization in an effective and efficient manner. Measuring how well organizations make use of their resources is important for management and improvement purposes. Modeling techniques can be used to investigate performance analysis of a manufacturing organization. Models provide valuable abstractions of a system and may be built in many different ways and refined to different levels of detail. Simulation modeling is a valuable aid to a manufacturing enterprise design, as it enables the progressive evaluation of potential performance of the proposed enterprise throughout the design and production process. Without statistically valid experimentation, a model cannot satisfy management goals. Simulation experiments can help to improve the operating of such manufacturing systems. This paper presents a practical approach to conducting a simulation experiment with the help of an expert system supported simulation experimenter. An approach to the design of a simulation experiment is used to minimize the number of experiments. The framework of a simulation experimenter and its running interfaces is also depicted.

Keywords: Expert System, Performance Evaluation, Simulation Experimenter

1. INTRODUCTION

Practical simulation modeling will usually originate in a management perception of a problem requiring a decision. The decision to be taken may concern or involve the operation of some complex system in which direct experimentation may be impractical on the grounds either of cost, time, safety, and perhaps even ethics.

In analyzing innovative manufacturing approaches, simulation has proven to be an important computerized tool [1]. Simulation modeling is one of a number of tools and methods available to support the analysis and design of manufacturing systems. This powerful tool is often used in the design phase of manufacturing systems. Using simulation modeling, the performance of various layout alternatives can be studied easily and quickly. Moreover, using computer animation, the operation of an entire factory can be viewed before the costly implementation of various production control strategies.

Any simulation modeling approach will require that a detailed understanding of the purpose of modeling is made explicit. This is the problem to be solved as seen by management; it must be defined and an appropriate problem domain must be determined. The modeler will have to decide the boundaries of the system to be modeled and the level of detail of the proposed model [2]. Within the boundaries of the system to be modeled and the level of detail, the input interrelationships of system components must be identified and described. Similarly the nature of output effects beyond the problem boundaries must be understood and properly defined.

2. HYPOTHESIS OF EXPERIMENTAL DESIGN AND ANALYSIS

In recent years, much simulation software has been developed to build a sound simulation model but almost none or very little efforts have been devoted to simulation experimentation. Enterprise engineers or simulation analysts can design a simulation model effectively but an actual performance of the proposed industry would be investigated through running a certain number of experiments. Designing a methodology for performing simulation experiments could help the enterprise management/engineer to identify the critical performance criterion of an enterprise. Experimentation with simulation models offers the modeler the prospect of working within a world in which the experimenter has total control. With the exception of cases where an observed input sequence serves directly as a model input, all features of the world are of necessity observable and under the potential control of the modeler.

A simulation experiment will typically involve the running of a complex model whose dynamic characteristics will be a function of many factors, including parameter values of component distributions of duration and the like, certain input data streams such as the particular arrival sequence experienced, and the logic of systems operation often embedded within the coding of the model. The computer model then acts as surrogate for the real world system in the experimentation to determine the effects of various factors of system operation on the levels of system performance as reflected in certain output measures.

Experimental design of a simulation model is a strategy of planning, conducting, analyzing and interpreting experiments so that sound and valid conclusions can be drawn efficiently and economically. It provides the experimenter a greater understanding and power over the experimental process. The simulation experiment ideology must support designers to define the objectives of the simulation and to identify the performance measures relevant to the objectives. The simulator then designs appropriate experiments, executes a series of simulation runs, records the results and performs an analysis of the results.

Montgomery and Bettencourt [3] and Hunter and Naylor [4] claim that computer simulation experiments are conducted mainly for two purposes

(i) to determine the relationship between dependent (response) variables and independent variables (factors) to identify the independent variables that have the greatest effect on response and to study the interactions between independent variables; and
(ii) to find the configuration for independent variables that leads to the optimal solution.

Biles [5] focuses on experimentation rather than model development in computer simulation. He classifies experimental designs according to their applications to computer simulation as: (1) factor screening experiments, (2) experiments of comparison and (3) response surface experiments.

Factor Screening Experiments: Here the purpose is to identify the important factors judged worthy of further investigation. In literature a significant number of experiments found aim at factor screening. Mauro and Smith [6] state the need for factor screening in the early stages of an analysis where too many factors are involved. The classical designs proposed by Plackett and Burman [7] are often used in literature for screening purposes you didn't explain it, I asked you to give a brief explanation here. One other approach to factor screening is to use 2^k full or 2^{k-p} fractional factorial designs mainly for two reasons. Firstly, when there are a large number of factors, the system is affected primarily by only a few of these factors and low-order interactions. Secondly, it is possible to combine two or more fractional factorial designs and have a larger design to estimate the effects of the factors and interactions.

Experiments of Comparison: The purpose in many simulation experiments is to compare the system performance measure(s) at different levels of a controllable factor. These experiments are called experiments of comparison. Biles [5] suggest 2^k factorial designs and 2^{k-p} fractional factorial designs for experiments of comparison. Analysis of variance (ANOVA) procedures is often used to evaluate the results obtained from these designs and to test the null hypothesis that individual factors or two factor interactions have no influence on the performance measure.

Response Surface Experiments: In the literature there are numerous applications of the Response Surface Methodology (RSM) to simulation analysis. The purpose of these applications is usually to come up with an empirical metamodel of the system's response. Kleijnen [8] defines the purpose of metamodelling as a method by which to measure the sensitivity of the response to various factors that may be either decision variables or environmental variables. Such a model is usually built by running a special RSM experiment and fitting a regression equation that relates the response to the independent variables or factors. The regression equation is usually fit by using the least squares method. The model is then used to predict the response at levels of factors that are not included in the original experiment and to optimize the system's output.

3. OBJECTIVES OF THE RESEARCH

Simulation is a valuable aid to a manufacturing enterprise design, as it enables the progressive evaluation of potential performance of the proposed enterprise throughout the design process. Simulation helps to measure the performance of the enterprise under study before implementation of a system. It helps the management to decide whether the design or redesign of a system is feasible and worthwhile or not. The objectives of the proposed work can be summarized as follows:

- To develop an expert system for designing and conducting a set of simulation experiments;
- To identify the specification / protocol of an experimental design;
- To execute and monitor the whole simulation scenario.

Simulation experimentation works on this hypothesis as a 'what if' scenario within a model to decide the optimum design parameters. It helps to identify the design parameters that need special attention for better performance. The objective of the research is to generate a specification/protocol to design an experiment for a specific simulation model.

The proposed research will be conducted by experimenting different design scenarios of a production enterprise. Design parameters such as buffer stock, queue length, machine utilization, material handling movement, and so on, will be tested through repeating experimentations run to find out the optimum value for each. Before running the experiment, a model of the proposed process outline should be developed with the help of available simulation softwares. The proposed simulation experimenter has to be fed through these experimental results and the output will be obtained through spreadsheet software. The experimenter will be developed through object-oriented programming language interconnected with database.

The results of the experimental output will then be transferred to the simulation analyst/modeler through readable command files. These command files help to build experimental design and analysis thorough database packages like Oracle. Design knowledge from simulation experimentation enables designers to experiment with different operational scenarios and facilitate assessment of the enterprise's performance under a variety of conditions. A significant role of simulation experiment and design is therefore to support expert guidance to the design team in setting up minimally adequate experimental protocols to provide the predictions required at the current stage of design [9]. It will also need to manage the experimentation and manage the recording of the experimental results.

4. OUTLINE OF SIMULATION EXPERIMENTER

An example of a decision flowchart for a simulation experimenter incorporating a factor, such as maximum utilization of a particular resource, is presented in Figure 1. It shows an experimental framework to find the bottleneck of the resource through performing a simulation experiment. The steps in the flowchart are to assess the impact of a particular parameter of consideration and execute its effect on other parameters. Different design parameters/variables of an enterprise layout can be experimented and evaluated thorough this software tool. Organizational managers will be able to use the flowchart to arrive at required design decisions based on the operating parameters of his/her enterprise. Individual and/or group performance criterion can be tested to determine the optimal ones. Bottlenecks of different design parameters can be identified and corrected for the more appropriate one. In this way the integration of simulation into the wider process of manufacturing enterprise design can be evaluated and implemented.

Figure 2 depicts the application of an experimenter in a distributed environment where the design parameters are fed through different simulators. A design team will commonly undertake the design or redesign of a part or all of a manufacturing enterprise or system. A team is necessary to ensure that a satisfactory mix of managerial and specialist knowledge and expertise is available to fully examine the objectives of the design task and produce a quality design which has been analyzed and evaluated from many different perspectives. To guide a design team, the simulation experimenter can help to perform the optimum design output, as depicted in Figure 2. The initial proposed design plan is modeled first with the help of different simulation softwares; here we named this as 'Simulator'. Individual simulators then run the experiment with their own built models and the different experiment's output are then collected and tested through the experimenter. In the simulation experimenter, the data is then analyzed and evaluated for the best-recommended design output. If the evaluation output is not suited with the design demanded, it is then further monitored and evaluated for the best one. It is a continuous updating process of evaluation.

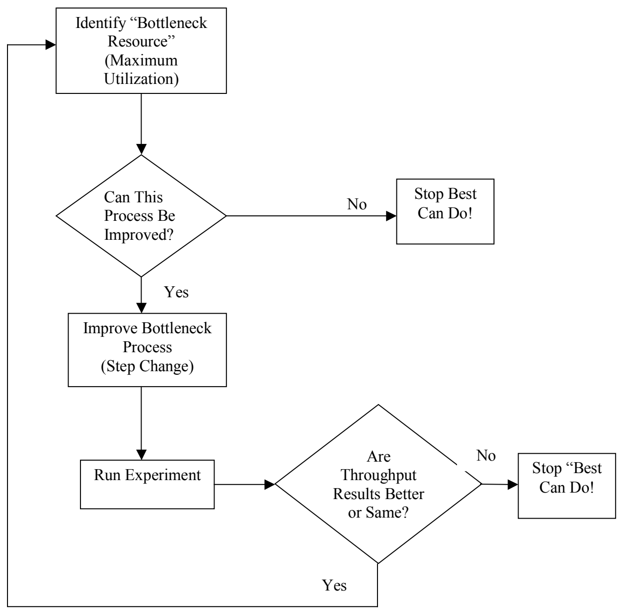

Fig. 1: Flow diagram of a simulation experimenter

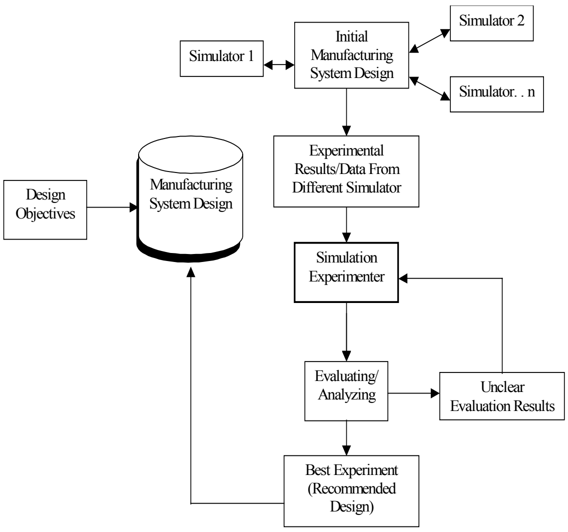

Fig 2. Distributed manufacturing system design using simulation experimenter

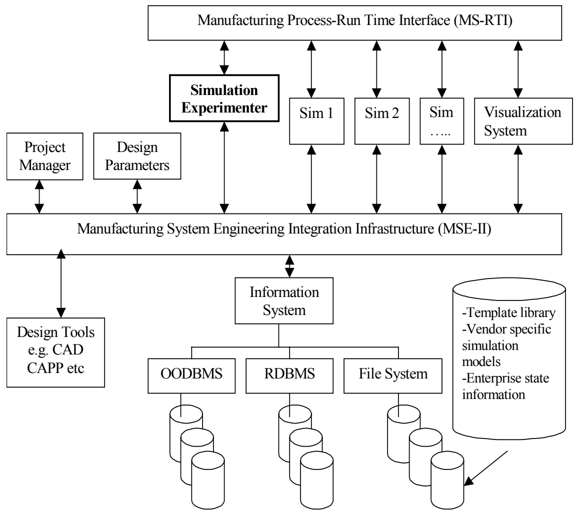

Fig. 3. Implementation architecture of simulation experimenter

5.IMPLEMENTATION ENVIRONMENT OF SIMULATION EXPERIMENTER

The proposed work would be implemented within architecture as depicted in Figure 3. This architecture shows the integration of different design agents necessary within a Manufacturing System Engineering (MSE) process. The MSE Integration Infrastructure (MSE II) provides the mechanism for interfacing software agents that participate in the MSE process. The requirement is to allow sharing information generated by any one component amongst all components that may have an interest in that information.

These software packages carry out an updating work over the different objects in the repository. To perform this task, they must somehow have access to that data and be able to interconnect between them. In this way, the work performed by one can be used by the others. This exchange of data requires a specific communication bus.

The proposed expert system shown in Figure 3 is a Simulation Experimenter. The Simulation Experimenter acts as a connection bridge for exchanging information between MSE II and Manufacturing System Run Time Interface (MS-RTI). It uses the information from different database/template libraries and the information collected during the MSE process to construct a distributed simulation scenario that supports the design of simulation experiments and executes the design. The Experimenter allows experiments or optimization by varying simulation parameters automatically. The Experimenter is an idea to have support mechanisms for the optimization of simulation scenarios. The results of experiments are the predictions of manufacturing process performance that is made available through the MSE-II to other components within the design agents.

6. SIGNIFICANCE OF THE WORK

Experimentation with simulation models offers the prospect for the modeler of working within a world in which the experimenter has total control. With the exception of the cases where an observed input sequence serves directly as model input, all features of the world are of necessary observable and under the potential control of modeler. A basic observation to be made at this point is that the very extent of control possible to the simulation experimenter is itself a source of problems. In particular the experimenter in determining a replication has to rerun the experiment under identical conditions. Taken literally this implies that the response measurements should also be identical. In the usual real world experiment, there are a multitude of small random effects which are beyond the control of the experimenter and which will produce the random variability of response justifying the normality and independence assumptions of the usual statistical metamodel.

A simulation experiment will typically involve the running of a complex model whose dynamic characteristics will be a function of many factors including parameter values of component distributions of duration and the like, and certain input data streams such as the particular arrival sequence experienced and the logic of systems operation often embedded within the coding of the model. The computer model then acts as a surrogate for the real world system in the experimentation to determine the effects of various factors of system operation on the levels of system performance as reflected in certain output measures. The simulation experimenter designs appropriate experiments, executes a series of simulation runs, records the results and performs an analysis of the results. The decision-maker may view the impact of various decisions to assist in the selection of the most appropriate strategy.

7. DISCUSSIONS AND CONCLUSION

Though simulation has become a major tool in studying discrete manufacturing systems, experimental issues have started to receive much attention. Although the importance of proper experimentation is often emphasized in the literature on discrete event simulation, it is neglected in most simulation studies. The main reason for this neglect is that the design and analysis of a simulation experiment requires expertise in experimental design methodology as well as familiarity with traditional statistical output analysis methods. The key to success in using designed experiments is not just the design and analysis but also conducting the experiment.

The approach outlined in this paper proposes a specification for a Simulation Experimenter, an expert support system of an extendable range of specialist design agents to support the effective design or redesign of manufacturing systems. Such agents provide vital support and expertise to enhance the activities of a design team working in a distributed environment. The proposed Simulation Experimenter enables better use to be made of distributed simulation systems, shared design information, comprised of a combination of both human and machine knowledge.

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