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Importance of Simulation in Manufacturing

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***Abstract*—Simulation is a very helpful and valuable work tool in manufacturing. It can be used in industrial field allowing the system`s behavior to be learnt and tested. Simulation provides a low cost, secure and fast analysis tool. It also provides benefits, which can be reached with many different system configurations. This paper is a review on research efforts in simulation.**

Keywords*—*Manufacturing, modeling, simulation, training.

I. INTRODUCTION

Introducing change can be a hard task for any organization, big or small. For this purpose modeling of complex systems such as manufacturing systems is an arduous task. Simulation in Manufacturing has become crucial in the recent few years and provides opportunities for designers to imagine new systems and helping them to both quantify and observe behavior. Irrespective of whether the organization is a an operating room, an emergency response system, production line, simulation can be used to study and compare alternative designs or to troubleshoot existing systems. With simulation models, how an existing system might perform if altered could explored, or how a new system might behave before the prototype is even completed, thus saving on costs and lead times. Modeling and simulation are growing as important technologies to support manufacturing in the 21st century. But, there are differing opinions on how best to develop, validate and use simulation models in practice. Most development procedures tend to be linear and prescriptive by nature. Several researchers have studied performance by using simulation techniques with the first uses dating back to at least the early 1960`s. Detailed discussions of simulation. In general, may be found in Banks, Carson, and Nelson [1] and Law and Kelton [2]. A practical discussion of the steps in a sound simulation study is given in Law and McComas [3]. Scriber described a case study for selecting the best probable production system from four proposed production systems using simulation [4]. Azadeh developed an integrated simulation model which generates a set of optimizing alternatives for a heavy continuous rolling mill system in a full-scale steel-making factory and generates a set of optimum production alternatives [5]. Patel et al. discussed the System of the automobile manufacturing process in order to develop an effective and efficient process to ensure the system throughput [6]. Choi et al. discusses initial efforts to implement simulation modeling as a visual management and analysis tool at an automotive foundry plant manufacturing engine blocks [7]. Potoradi et al. described how a large number of products are scheduled by a simulation engine to run in parallel on a pool of wire-bond machines to meet weekly demand [8]. Kibira et al. presents a virtual-reality simulation of a design of a production line for a mechanically assembled product [9]. Altiparmak et al. used simulation met models to improve the analysis and understanding of the decision-making processes of an asynchronous assembly system to optimize the buffer sizes in the system [10].

Wiendahl et al. used simulation tools in the field of assembly planning and due to the different objectives of the different efforts, the tools are divided into the four-hierarchy classes of an assembly shop, cell, station and component [11]. Gurkan et al. investigated current problems in an order based weaving mill so as to propose a new system for the aforementioned mill [12].

II. APPLICATION

The following are some of the specific issues that simulation is used to address in manufacturing:

- Number and type of machines for a particular objective
- Number, type, and physical arrangement of transporters, conveyors, and other support equipment (e.g., pallets and fixtures)
- Location and size of inventory buffers
- Evaluation of a change in product volume or mix
- Evaluation of the effect of a new piece of equipment on an existing manufacturing system
- Evaluation of capital investments
- Labor-requirements planning
- Throughput analysis
- Time-in-system analysis
- Bottleneck analysis
- Production scheduling
- Inventory policies
- Control strategies [e.g., for an automated guided vehicle system (AGVS)]
- Reliability analysis (e.g., effect of preventive maintenance)
- Quality-control policies
- Throughput
- Times parts spend in queues
- Queue sizes
- Timeliness of deliveries
- Utilization of equipment or personnel

III. MANUFACTURING SIMULATION MODEL

The assembly line simulation model recreates all the operations previously described in a three-dimensional virtual environment. The modeling phase can be subdivided in two main steps:

- Plant lay-out generation;
- Human models inserting and characterization.

The plant lay-out has been designed using CAD software, importing and directly opening all the generated files in eMWorkplace. The plant lay-out organization reflects the results obtained applying one of the traditional methodologies for plant lay-out study and analysis [13], [14].

For what concern human models they can be imported from software libraries and inserted in the simulation model. At the beginning the human model is only able to stand in his waiting position. In order to recreate all the assembly operations it is required to "train" the human model. Each operation is subdivided in basic motions and for each basic motion the software asks to the user to insert specific code consequently allowing the human model to perform the required operations. Particular attention must be paid for information regarding grasp and release operations and the relative human model concentration index as well.

The intrinsic difficulty of such modeling approach is due to the high quantity of information and data required to properly set the human models and the plant lay-out elements. In fact in addition to the motions sequences it's required to insert data regarding:

- Age, gender, physical characteristics, health conditions, skills, efforts, consistency and performances of each human model;
- Weights and dimensions of objects together with grip quality;
- Weight and dimensions of tools used during the operations;
- Worker posture at the origin and destination of lifting operations;
- Frequencies and duration of lifting tasks;
- Process and set-up times of operations not performed by human models [15].

After the modeling phase the successive step is the validation.

IV. VALIDATING THE MODEL

Validation is necessary to show that the proposed model has an acceptable level of confidence in the performances processing assumed. Validation is also associated with whether the proposed model is indeed an accurate representation of the real system.

A simulation model is a surrogate for actually experimenting with a manufacturing system, which is often infeasible or not cost-effective. Thus, it is important for a simulation analyst to determine whether the simulation model is an accurate representation of the system being studied, i.e., whether the model is valid. It is also important for the model to be credible; otherwise, the results may never be used in the decision-making process, even if the model is "valid."

The following are some important ideas/techniques for deciding the appropriate level of model detail (one of the most difficult issues when modeling a complex system), for validating a simulation model, and for developing a model with high credibility:

- State definitively the issues to be addressed and the performance measures for evaluating a system design at the beginning of the study.
- Collect information on the system layout and operating procedures based on conversations with the "expert" for each part of the system.
- Delineate all information and data summaries in an "assumptions document," which becomes the major documentation for the model.
- Interact with the manager on a regular basis to make sure that the correct problem is being solved and to increase model credibility.
- Perform a structured walk-through (before any programming is performed) of the conceptual simulation model as embodied in the assumptions document before an audience of all key project personnel.
- Use sensitivity analyses to determine important model factors, which have to be modeled carefully [2].
- Simulate the existing manufacturing system (if there is one) and compare model performance measures (e.g., throughput and average time in system) to the comparable measures from the actual system.

V. SIMULATION SOFTWARE FOR MANUFACTURING APPLICATIONS

Most organizations that simulate manufacturing or material-handling systems use a commercial simulation software product, rather than a general-purpose programming language (e.g., C). Furthermore, the two most common criteria for selecting simulation software are *modeling flexibility* (ability to model any system regardless of its complexity or uniqueness) and *ease of use*.

We now define the major types of simulation software for manufacturing. A *simulation language* is a software package that is *general in nature* (in terms of the applications it can address) and where model development is done by "programming." Traditionally, programming meant the development of a simulation model by writing code, but in recent years there has been a strong movement toward simulation languages that employ a graphical model-building approach. Example of simulation languages are Arena, AweSim!, Extend, GPSS/H, Micro Saint, MODSIM III, SES/*workbench*, SIMPLE++, SIMSCRIPT II.5, SIMUL8, and SLX. The major advantage of a *good* simulation language is

modeling flexibility, whereas the major disadvantage is that programming expertise is required.
A *manufacturing-oriented simulation language* is one where the modeling constructs are specifically oriented toward manufacturing or material handling.

Examples of such software are AutoMod and Quest. One advantage of this type of software is that programming time may be reduced (compared to a simulation language) due to powerful constructs for such things as conveyors and AGVS.
In the last five to ten years, there has been considerable interest in having simulation software that is easier to use, which largely means reducing the amount of programming required to build a model. This has given rise to what we call a *manufacturing-oriented simulator*, which is a simulation package designed to model a manufacturing system in a specific class of systems. This type of software has two main characteristics:

- Orientation is toward manufacturing
- Little or no programming is required to build a model (relative to simulation languages)

Examples of simulators are FACTOR/AIM, ProModel, Taylor II, and WITNESS. A simulation model is developed using a simulator by using graphics (e.g., dragging and dropping icons), by selecting items from menus with a mouse, and by filling in dialog boxes. The major advantage of a simulator is that if it is applicable to your problem, then the amount of time required to develop ("program") the model may be reduced considerably. The major disadvantage of simulators is that they are not as flexible as simulation languages, since they do not allow full-blown programming as in simulation languages. Because a simulator that does not allow programming in any shape or form just cannot be as flexible as a simulation language, the vendors of the major manufacturing-oriented simulators have introduced programming into their software in one or both of the following ways:

- The ability to use "programming-like" constructs (e.g., setting values for attributes or global variables, if-then-else logic, etc.) at certain *selected* points in the model-building process
- The ability to call external routines written in a general-purpose programming language at certain *selected* points in the model-building process.

Simulators with either or both of the above programming options are still not, in general, as flexible as a *good* simulation language where anything can be programmed from scratch. For example, manufacturing simulators have such *fundamental* modeling constructs as machines, parts, and conveyors. Since in the real world conveyors can come in a myriad of forms, there is a good chance that none of the built-in conveyor options is completely correct. Furthermore, because of the fundamental nature of the conveyor modeling construct, it may not be possible to change their logic in a substantive manner.

The distinction between simulation languages and simulators has become less clear in recent years. Languages have gone to graphical user interfaces to increase ease of use and simulators have added some programming capabilities to increase modeling flexibility. However, we can still say that a simulation language is general in nature and uses programming (syntactical or graphical) to develop a model. Simulators, on the other hand, are application specific (for the most part) and, perhaps, at most twenty percent of the model is developed using some form of programming.

VI. BENEFITS OF SIMULATION IN MANUFACTURING

The use of simulation to check out and validate process automation systems, perform software acceptance tests and train operators provides numerous benefits to companies in the process industries. Some of these benefits are discussed below:

Changing workforce leading to skills gap, the loss unskilled workers to retirement reduce an organization's ability to identify production problems and take corrective action. Many plants are being operated with raw materials that change frequently based on market conditions. This creates constant swings and instabilities in unit operations. In addition, many units are run to capacity with sophisticated control equipment, making operations much more demanding.
Human errors are costly not only in terms of waste, equipment failure, environmental catastrophes and worker safety. With today's business demands and aging workforce, the need for well-trained operators is increasing.

Operator training simulators (OTSs) remain one of the best ways to train new operators and refresh skills of experienced ones. OTSs enable operators to learn the functionality of the process automation system without the pressure of controlling the actual plant. Both normal and abnormal situation training are possible without jeopardizing the plant, environment personnel.

Simulator justification, most often, the justification for acquiring an OTS is based on estimating the reduction in losses. This is easy for high-capacity plants where savings approach millions of dollars for a few days of lost production. Typically, OTSs are purchased as part of a new plant construction project or a major plant or automation upgrade where large capital budgets absorb the cost. Justification comes from the ability of the simulator to check out the automation system and provide operators with a better understanding of a new process. With greater exposure to the simulator, operators gain the confidence to bring the plant up and running quicker, thus shortening startups significantly. Some forward-thinking companies are purchasing OTSs from operating budgets. These companies acquire (OTSs to improve the proficiency of less-experienced operators in existing plants.

Simulation offers substantial business benefits. The direct benefit of a simulator is difficult to ascertain. A study conducted by The Electric Power Research Institute (EPRI) estimates a payback of about three months. The savings are attributed to reduced training costs; costs caused by environmental excursions, damage to equipment and improved plant availability. Other companies have conducted, studies on the benefits of OTSs. One company cites that for its ethylene OTS, the benefits come from four quantifiable categories: initial startup savings of eight days, one saved day on subsequent startups on each turnaround, two production days saved each year from improved recovery from upsets and 1% improvement in costs through better plant control [17]. *Enhancing human performance through training*, OTSs are the preferred method to train and certify operations staff prior to plant startup and production. Training operators prior to startup accelerates the learning curve on the new process and automation system. In addition, operators can be trained on upset or emergency conditions that they would normally not encounter during day-to-day plant operations.

Simulation reduces risk and startup times. One of the greatest risks of automating a process facility is to ensure that the quality of the automation system application software meets the production requirements of the organization.

Without using a simulation system, the user has no ability to test the application software thoroughly before actual startup and production. Identifying and correcting errors in the offline simulation environment costs 10—100 times less than in the online plant environment [17].

Simulation system considerations, to improve ROI from simulation systems, users are adopting best practices for implementing automation system testing and training. To reduce commissioning time and cost, developing simulation models, testing and training are becoming an integral part of the overall automation project life cycle management strategy. Simulation model development, testing and training are not a one-shot deal, but an incremental approach, tightly integrated with the automation project life cycle. This "ground-up" testing facilitates identifying and eliminating errors early in the project cycle before being propagated throughout the system. As all plants change over time, especially during the first year or two after commissioning, it is important to have resources available to keep the models up-to-date. In addition, companies are establishing comprehensive testing and training programs. OTS is only one element of a good training program. Other elements include course work, site visits to similar plants, and computer based training to name a few[16].

VII. CONCLUSION

The simulation model recreates all the assembly operations in a three-dimensional virtual environment giving the possibility to see, during the animation the human models performing the required operations. In such context the simulation has been used as cognitive tool. In fact the validation of the simulation model has required detailed discussions with system's experts as well as iterative integration of sequence motions.

For most simulation studies of manufacturing systems, we are interested in the long-run (or steady state) behavior of the system, i.e., its behavior when operating in a "normal" manner. On the other hand, simulations of these kinds of systems generally begin with the system in an empty and idle state. This results in the output data from the beginning of the simulation run not being representative of the desired "normal" behavior of the system. often run for a certain amount of time, the warm-up period, before the output data are actually used to estimate the desired performance measure. The use of simulation to check out and validate process automation systems, perform software acceptance tests and train operators provides numerous benefits to companies in the process industries. These benefits are from enhancing operator performance to incident avoidance.

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