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Extending Simulation's Advantages to Novice Model Builders: IntelliSIM Tutorial

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EXTENDING SIMULATION'S ADVANTAGES TO NOVICE MODEL BUILDERS: INTELLISIM TUTORIAL

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ABSTRACT

The potential benefits that discrete-event simulation offers are impeded by the high level of expertise necessary to successfully conduct a sound simulation study. As a solution, this paper introduces IntelliSIM, an intelligent simulation environment. Using this environment makes simulation more accessible to users by reducing the need for extensive experience or training. One of IntelliSIM's key features for accomplishing this is a tutorial and training module that quickly acquaints a novice simulation user with IntelliSIM's features and the process of performing a simulation study. This paper discusses this tutorial by explaining how IntelliSIM develops a simulation model, thus illustrating how the benefits of simulation can be extended to a broad base of business/systems modelers.

INTRODUCTION

Since 1987, the research efforts of the Systems Simulation Laboratory (SSL) at Arizona State University have resulted in the development and release of three prototype intelligent simulation environments (Mackulak and Cochran 1987, 1989). Out latest implementation of research concepts has resulted in IntelliSIM (**Intelli**gent **Sim**ulation). This tool is an intelligence-assisted simulation environment that allows a modeler to predict the performance of any manufacturing system for which the necessary data is available. Using this environment allows the benefits of discrete-event simulation to be exploited without requiring the high level of modeling and statistical expertise necessary to conduct a sound simulation study.

Simulation modelers make errors. Typical errors include too much detail in the model, too little detail, generating the wrong output, or incorrectly applying statistical techniques. In seeking to minimize these misapplications of simulation, the modeling approach of IntelliSIM differs from most non-programming commercial packages (SIMFACTORY, WITNESS, ProModel, etc.). With IntelliSIM, a modeler does not "build" a simulation model, but rather "uses" a pre-existing generic model selected from a database of models of typical manufacturing systems (Ozdemirel and Mackulak 1993). Such an approach makes simulation more accessible to users by reducing the need for extensive experience and training.

Our goal when developing the IntelliSIM environment was to allow modelers to concentrate on solving their simulation problem instead of the mechanics of building a model or using the software. A top priority was to insure that a person knowledgeable about the operation of their factory be able to quickly perform simulation studies with the package. To assist in this process, a tutorial and training module exists to quickly acquaint a new user with the features of IntelliSIM. The tutorial provides this introduction while also demonstrating the process (methodology) of performing a simulation study.

The objective of this paper is to discuss the IntelliSIM tutorial which explains how IntelliSIM develops a simulation model of a manufacturing cell. We first describe the four station manufacturing cell that is illustrated in the tutorial. We next explain the process of selecting and configuring a simulation model. We continue and show the type of graphical output generated from executing the tutorial example. Finally, we conclude with a discussion on how IntelliSIM simplifies the model development so as to make simulation available to a wider range of users.

MANUFACTURING CELL DESCRIPTION

The objective of the tutorial is to provide a novice simulation modeler with a sufficiently real example to demonstrate correct simulation methodology and to illustrate IntelliSIM's capabilities

The tutorial case study consists of a manufacturing cell (see Figure 1) with three production stations and one packing station. It was adapted from the operation of a major electronics manufacturer with the objective of determining part cycle time and utilization of the cell given a proposed raw material arrival rate.

STATION 3

Loading and
unloading of
product from the
AGV is done
manually (1 person
assigned to each
station)

3 machines

INPUT   OUTPUT

STATION 1

INPUT

OUTPUT

STATION 4

INPUT

OUTPUT

Station
Input and
Output Queues

AGV for
material
handling
between
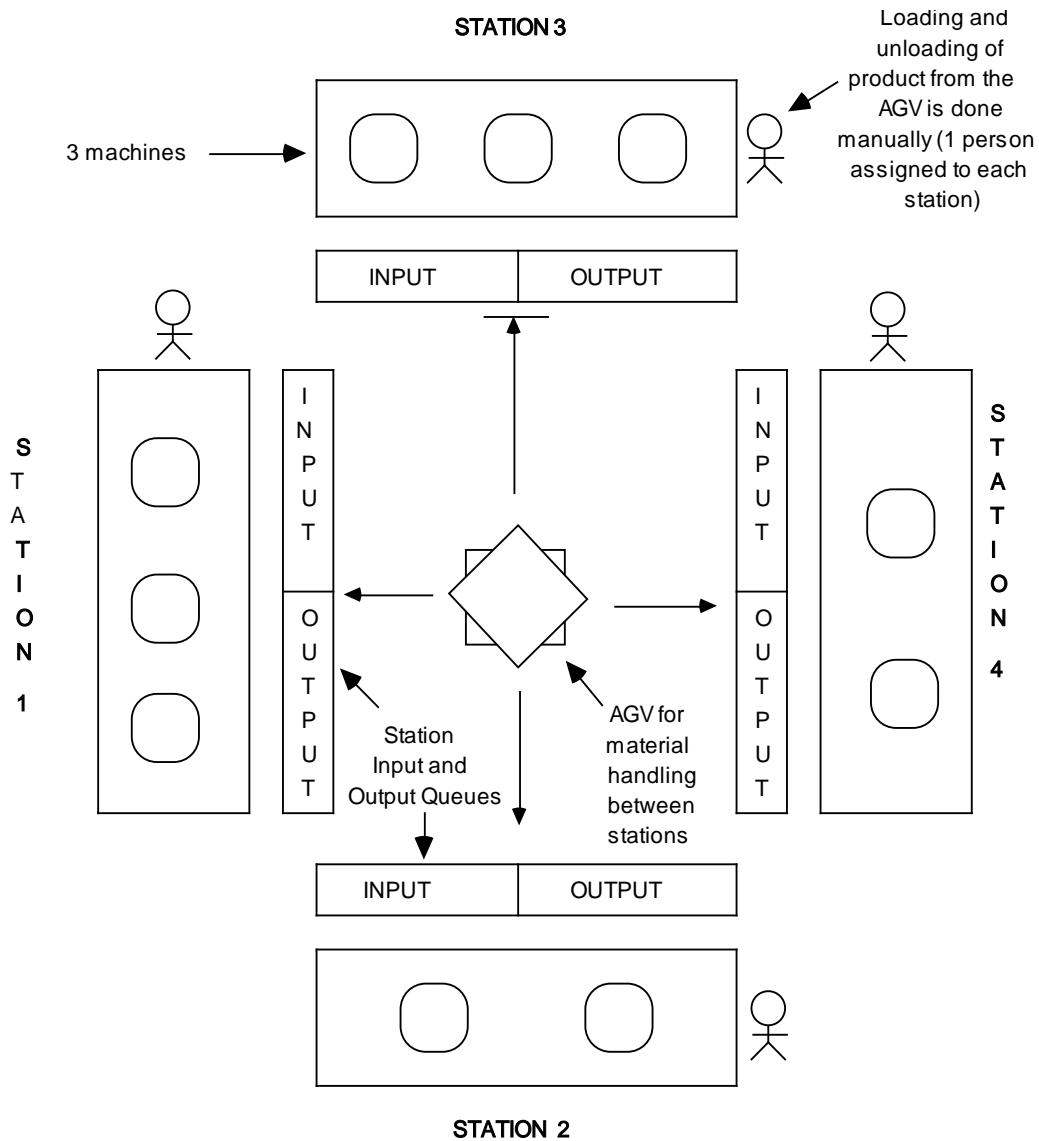stations

INPUT   OUTPUT

STATION 2

Figure 1.   Physical layout of the manufacturing cell (picture out of proportion)

Stations 1 and 3 can each run up to three machines while stations 2 and 4 can each run up to two machines. The distances between all stations is 30 meters. As such, it takes an equal amount of time to move the semi-finished product from one station to another using a single automated guided vehicle (AGV) which has a speed of 75 meters per minute.

For the tutorial example, only two products are produced by this manufacturing cell. The schedule calls for raw material to arrive at the cell every 3.5 minutes. Sixty percent of the products are Type 1 and forty percent are Type 2.

There are input and output queues at each of the stations. The capacity of each queue is 50 parts (Type 1 and Type 2 parts are approximately the same size). The AGV carries one part at a time and cannot unload if a destination queue is at capacity.

The production sequence for each product is the following:
• Type 1: Station 1 - Station 2 - Station 3 - Station 4 (Packing station)
• Type 2: Station 1 - Station 3 - Station 4 (Packing station)

Processing, loading and unloading times for each type of machine are shown in Table 1. Each station is assigned one operator for performing the manual operation of loading and unloading of a part from the machine. The setup time for the machines is negligible and is not considered for the purposes of analysis.

Table 1. Processing, loading and unloading time for each of the stations in the manufacturing cell.

Station	Processing Time (minutes)	Load/Unload Time (minutes)
1	Between 2.0 and 3.0	Between 1.0 and 1.5
2	Between 3.0 and 4.0	Between 1.0 and 2.0
3	Between 2.0 and 3.0	Between 1.0 and 1.5
4	Between 2.0 and 3.0	Between 1.0 and 1.5

With the goal of estimating the cycle time of parts through the manufacturing cell, the simulation run length is initially established to be 500 minutes.

MODEL SELECTION

A fundamental problem of simulation modeling is that modelers view models as unique and tend to recreate topologically similar systems when only the parameters are different. As such, Hertel and Merikallio (1974) estimate that development of a simulation model accounts for 50% to 80% of the total simulation cost. As a solution, the underlying modeling approach used by IntelliSIM is to use pre-existing (generic-specific) models of manufacturing situation. Such a technique allows the analysis to concentrate on collecting domain knowledge from the industrial setting and answering the design questions at hand, thus reducing the time and experience normally required for model development.

The use of generic-specific models is a process where, through the assistance of an expert system, a modeler selects a pre-existing generic model and fine-tunes it (makes its specific) to solve a problem (Mackulak and Cochran 1990a, 1990b; Manathkar et al. 1992). A generic model is an empty model (it lacks simulation data) of typical manufacturing situations, while a specific model is one in which simulation data about the particular manufacturing system has been defined. Through user interaction, a generic model becomes specific by specifying the data and experimental conditions of the simulation study.

The first task in developing a simulation model with IntelliSIM is to select a generic model that meets the assumptions of the manufacturing system under study. Unfortunately, most simulation practitioners require some type of expert assistance when faced with this modeling effort. IntelliSIM's solution is to provide an expert system to guide a modeler through the three steps involved with selecting a generic model.

The first step, meta-level query, explores whether simulation is an appropriate tool for the analysis and determines if IntelliSIM is capable of modeling the problem. The questions asked are summarized in Table 2. Their objective is to compare the scope and general capabilities of IntelliSIM versus the user's requirements and the nature of the manufacturing process under study.

Table 2. Meta-Level Query questions. Questions are to test whether simulation and IntelliSIM are appropriate tools for modeling the system under study.

Question
Does your process manufacture discrete parts?
Does your process involve continuous manufacturing such as chemical processing plants?
Does your process perform an operation on a part while the part is in transit on a material handling device?
Is your system a pure automatic storage/retrieval system, such as a warehouse, with no manufacturing processes?
Do you have more than 50 unique work stations?
Are operation sequences for different job types known prior to the start of production?
Is data available for the interarrival processing time of different job types?

Upon the successful conclusion of the meta-level query, a user may choose to compare their manufacturing system to the generic modeling assumptions. These assumptions reflect the strengths and weaknesses of the generic models.

Following the task of reviewing assumptions, the expert system assists the modeler in choosing one of the possible forty generic models. Through a series of questions regarding the manufacturing system (e.g., arrival process, type of production flow, etc.), the expert system displays a group technology (GT) code describing the appropriate generic model [see Ozdemirel et al. (1993) for a description of the code].

This model selection process loads a generic model and prepares it for configuration. The GT code of the generic model describing the tutorial example is GQ1S02.mod. Selection of this model is based on an IntelliSIM recommendation after a session with the expert system. This model was chosen because the manufacturing cell has one worker used for loading and unloading at each station and there are separate work-in-progress areas for incoming and outgoing jobs. Be aware that if the case study specifications were different, another generic model would possibly of been recommended by IntelliSIM.

The next step in developing a model using IntelliSIM is to input the specific system data describing the manufacturing system. Using a series of menus and windows, IntelliSIM guides a user through this configuration process of making a generic model become specific through user interaction. After entering all this data, a configured generic model is saved as a specific model. IntelliSIM next controls the a model's evolution by running the simulation model and generating simulation output.

Figure 2. Confidence intervals and percentage error for each batch

MODEL EXECUTION AND OUTPUT ANALYSIS

Most novice simulation modelers do a poor job of output analysis. They base their conclusions on a single simulation run or use on a simple mean value as their output estimate. IntelliSIM was designed to assist model execution and output analysis by performing *semi-automatic analysis*. This feature of IntelliSIM controls the simulation model run length and develops confidence intervals on the output. It operates by having the user select the most important statistics sought from running the simulation model. This statistic is termed the priority variable. While the simulation model is running, the semi-automatic analysis feature displays the confidence interval and percentage error for this selected priority variable on-screen at the completion of every batch of thirty observations.

IntelliSIM continues running the simulation until the user presses the <END> key on the keyboard or until the percent error of the confidence interval is less than five percent. Once stopped, IntelliSIM graphically displays the results of the confidence interval building and percent error to aid the user in making decisions. In addition, a standard numerical summary report is developed.

For the manufacturing cell example, the priority variable is overall time in the system for both part types. Figure 2 displays the confidence interval and percentage error for each batch that is displayed on-screen during the model execution. Figure 3 presents the graphical summary of the confidence interval building process displayed by IntelliSIM after the simulation model has been terminated.

Figure 3. Graphical summary of semi-automatic analysis

The simulation results of the mean cycle time are initially small with a high percent of error due to the simulation bias of an empty and idle system. As the system reaches steady-state, the mean cycle time rises and the percent error is reduced to nearly a fifth of the original error. The resulting confidence interval on the mean cycle time for the part types is (28.64, 31.61) minutes with a mean value of 30.13.

5   COMMENTS ON MODELING METHODOLOGY

Sadowski (1989) remarks that "although mistakes will be made [during modeling], hopefully the simulation tool will become a valuable addition to the analyst's set of capabilities." This demand for simulation tools has led to many advances in computer hardware and artificial intelligence. An emerging idea is of an intelligent simulation environment consisting of an integrated set of software and artificial intelligence tools for designing and using simulation models. In this paper, we introduces IntelliSIM, an example of such an environment.

To assist IntelliSIM users in learning simulation, a tutorial module is incorporated into the environment. The tutorial describes in detail how IntelliSIM is used for solving a four station manufacturing cell. Running the simulation model shows that even though the mean cycle time is initially low, it rises as the system reaches steady-state and the percentage error decreases. The results do indicate that the proposed manufacturing cell is capable of meeting cycle time requirements. It should be realized that case study is only a single illustration of IntelliSIM. IntelliSIM can be used for a vast variety of simulation models apart from that explained in this example.

With IntelliSIM, all stages of model development, execution, and analyses occur in the same integrated. The advantage of this approach is that the process of learning and using the environment is minimized through the development of more advanced components within the software. As a result, the benefits of simulation are available to a broader range of users.

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Figure 2.   Confidence intervals and percentage error for each batch

Figure 3.   Graphical summary of semi-automatic analysis