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Simulation Analysis of Flexible Manufacturing System for Performance Improvement

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ABSTRACT

The need for flexible processes is increasing day by day. It permits rapid low cost switching from one product line to another. This is possible with flexible workers whose multiple skills would develop the ability to switch easily from one kind of task to another. As main resources, flexible processes and flexible workers would create flexible plants which can adapt to changes in real time increase in production using movable equipment, knockdown walls and easily accessible and re-routable utilities. In this paper a real time simulation is done to find out the optimum values of production and operation variables.

Introduction

Increasing expectations of today's customers involving the quality and variety of produced goods are becoming more and more critical on the market. The fast changing tendencies on the market results in a shortened life cycle for products and a competitive market that forces the manufacturers to explore new markets to sell the goods. The requirements of the market necessitate the introduction of changes in the organization of production processes, through the launch of automation, computer aided design and manufacturing works and management, and the development of modern multi-stand machining systems, such as Flexible Manufacturing Systems (FMS).

One of the largest application areas for simulation modeling is that of manufacturing systems, with the first uses dating back to at least the early 1960's. Since then, it has been used effectively in the design and analysis of manufacturing systems. Law (1999) has identified specific issues that simulation is used to address in manufacturing as follows:

The need for and the quantity of equipment and personnel

- Number, type, and layout of machines for a particular objective
- Requirements for 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
- Number of shifts

Performance evaluation

- Throughput analysis
- Time-in-system analysis
- Bottleneck analysis

Evaluation of operational procedures

- 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

As seen from the above discussion, manufacturing and production offers a huge number of issues to deal with. Some of the recent applications of simulation and modeling in this area are given below. It should be noted that there are thousands of studies in this field, but the following are important as they mostly make examples of using ARENA in simulation. The work of Williams (2002) is important as it presents the usefulness of simulation in studying the impacts of system failures and delays on the output and cycle time of finished parts. Also, the similarity of the robotic work cell used as the modeling medium to our environment is worth mentioning. The case study illustrates a modeling approach with system verification and validation revealing fundamental system design flaws.

Patel et al (2002) have used discrete event simulation for analyzing the issues of first time success rate, repair and service routing logic, process layout, operator staffing, capacity of testing equipment and random equipment breakdown in automobile manufacturing processes. They offer concepts and methods for discrete manufacturing processes especially for the Final Process System for optimizing resources and identifying constraints. The ARENA product suite is designed for use throughout an enterprise, from strategic business decisions, such as locating capacity in a supply chain planning initiative, down to operational planning improvements, such as establishing

Flexible Manufacturing Systems

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FMS is defined as a computer-controlled configuration of semi-dependent workstations and material-handling systems designed to efficiently manufacture various part types with low to medium volume (Luggen 1991). It is an integrated production system composed by a set of independent machining centers. An automatic part handling system interconnects the machining centers to a group of part-storage locations such as loading/unloading positions and input/output buffers. An automatic tool handling system interconnects the machining centers to a group of tool-storage locations as tool magazines, tool rooms, exchangers and spindles. Either the part handling system or tool handling system mechanisms consist of one or more automated guided vehicles (AGVs) or transporters. A central supervisor (the FMS control software) monitors and manages the whole system (Anglani et al, 2002).

Operator interdiction is discouraged by FMS. As jobs are changed, the computer is reprogrammed to handle new requirements. The work pieces in FMS are usually complex, and can require complicated manufacturing steps. Production of the various parts requires processing by different combinations of manufacturing, but FMS is versatile and can perform different operations on a variety of products. Often an FMS machine can perform many processing steps. The process begins with a robot or operator loading or unloading a Computer Numeric Controlled (CNC) machine in the FMS. After processing in FMS, the robot returns the semi finished or finished part to the conveyor.

FMS is integrated with computer-aided design (CAD) and manufacturing (CAM). CAM, for example, limits the number of tools to a preset number, such that the factory does not store more than a specific number. Another approach finds the number of tools and then reduces that number by cost control methods. Standardization of tools, their kind and quantity, and specifications are a natural development of FMS (Ostwald and Munoz 1997).

Simulation Process

As Shannon states simulation is a continuous “process” rather than a onetime create-and-use application. Especially computer simulation is an iterative method that includes several stages as Kelton et al (2004) identifies. A simulation study starts with efforts on understanding the system in addition with the identification of the goals of the study. The life cycle of a simulation study has also been identified in detail by Balci (1990). This life cycle has been divided into 10 processes, 10 phases and 13 credibility assessment stages. According to (Sadowski 1999) a successful simulation project is the one that delivers useful information at the appropriate time to support a meaningful decision, which implies that there are three key elements of success in simulation; decision, timing and information. As outlined by Kelton et al (2004) the most realistic type of all, physical models include the tabletop models that act like the miniature versions of the actual facility or system, full scale versions of existing facilities used as mock-ups for experimentation, or flight or control room simulators used for training and emergency planning. Simulation has many benefits for the users as outlined by J. Banks (2000). First of all, it lets users choose correctly among the possible alternatives, provides time compression and expansion according to the type of the simulated event, equips the managers with the tools to understand “why?” certain phenomena occur in a real system. Banks (2000) underlines four main disadvantages of simulation. The first disadvantage is that model building requires special training and it is highly unlikely that models generated by different modelers about the same system will be the same. Altinkilic (2004) has presented a use of simulation to improve shop floor performance. The performance of the existing system is evaluated by using ARENA. Due to the motivation for redesigning the shop flow, manufacturing cells are performed and the performance of the new system is evaluated and compared with that of the current system. As a result, based on a simulation analysis, several recommendations are made to the management of the mentioned job shop production system.

Animation

Animation in simulation of FMS is excellent for communication and adding realization to models and it can also be used to debug the simulation program. Validation of simulation models usually require a well set up animation component for the modeler to observe the responses of the model to extreme conditions. Animation can be divided into two main headings as animation of processes and animation of statistics. Both are important in terms of helping the decision makers grab the necessary outcomes out of the simulation study.

Model Development

In this study, ARENA Simulation Tool is used to develop models. The capabilities of the software are utilized effectively to come up with models that are as realistic as possible. During model verification stage, each step of the execution has been traced extensively using both the ARENA and Visual Basics interactive debuggers and the detected errors in the models and modeling logic have been removed.

The generated models are different in terms of queuing methodologies however the structures of the developed models are common up to some extent. The sub models developed to construct the entire model are part creation, routing and assignment, AGV loading/unloading, selection rule, machining operations, stations, part disposal and data.

Part Creation Sub Model

The Part Creation sub model is responsible for the introduction of the parts to the models. The nature of this sub model is arranged so that it allows the selection of part arrivals either from a statistical distribution or from a Microsoft EXCEL file. In the first option the parts are generated from an exponential distribution of with a mean value of 5 minutes. This value may seem unrealistic when the nature of the FMS in hand is considered as it is not used intermittently; however if it were to be used continuously with work orders following one another, the parts that arrive in this time intervals would result in a steady state system. A creation limit of 180 parts is used, limiting the number of parts to arrive at the system for a day. The ASSIGN block next to the CREATE block is used to assign the attributes such as due dates and part indexes, to identify the created part. The second option at this stage is letting the user use the values entered to an EXCEL file as part arrival data. A single control entity is generated at the beginning of the simulation if this option is selected.

This entity is responsible for reading the values of part arrival times, the associated part indexes, due dates and priorities. The duplicated entity enters the system with attached data and the control entity keeps on looping until the last part data. Once the last line of data is input from the file, the control entity is disposed. Figure 1, shows the sub model's blocks and modules.

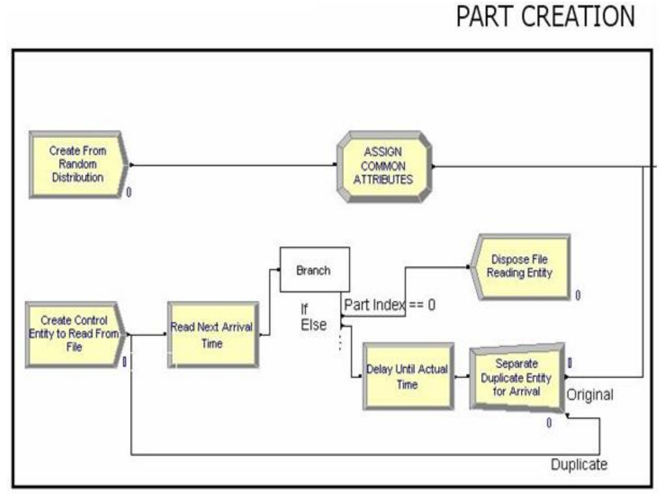

Figure 1. Part creation sub-model.

PART PROCESS PLANS

According to this layout, a part can have four possible process plans assuming that all operations of one single type (milling or turning) can be finished in one pass. The parts can have only one milling / turning operation or milling can follow turning or vice versa.

Part variability can be obtained by assigning different processing times for operations in the machines. The representation of entities that belong to the mentioned types is based on coloring in the simulation. Each type is shown with a different color and parts take the color of the type that they belong to. The types, associated colors and assigned machining sequences are given in Table 1.

Table 1. Part types, process sequences and durations.

PART TYPE	TURNING	MILLING	COLOR
1	2 / TRIA (2.4, 2.5, 2.6)	1 / TRIA (1.4, 1.5, 1.6)	YELLOW
2	-	1 / TRIA (2.8, 3.0, 3.2)	BRONZE
3	1 / TRIA (7.2, 7.5, 7.8)	-	RUBY
4	1 / TRIA (9.6, 10, 10.4)	2 / TRIA (5.6, 6, 6.4)	RED

In addition to coloring the parts, the completed level of th process plan can be followed on the parts. Each part that has finished its task on one of the machines takes a letter over its representing picture (M for Milling and T for Turning), which shows th completed tasks on the part. A part that has completed both of th operations has both T and M letters on it.

Test Scenarios

One of the main objectives of this work is to create a system that enables making comparisons between different production philosophies. A specially tailored bidding algorithm or a well known and easy to apply heuristic, each philosophy come with its own advantages and disadvantages. The simplest of all kinds, FCS (First Come Served), is considered as the first alternative to provide a basis for comparisons. The next alternative methodology to consider is First Come First Served (FCFS). This philosophy differs from the previous one, from the point of allowance of multiple numbers of parts in the system simultaneously.

As another alternative methodology, due dates of the parts are considered. Earliest Due Date (EDD) indicates the policy to accept the part with the earliest due date to the system, without considering any other property of the parts. For each simulation run, it is necessary to define some parameters beforehand. These parameters include, simulation dependent parameters such as run lengths, and model dependent parameters such as arrival schedules and due dates.

Run Results

ARENA itself provides the user with the opportunity to view several reports, comprising a great number of statistics kept within the system. However, the classification and interpretation of these is a time consuming and burdensome activity for the potential users that are not interested in details of the simulation models. The following results are taken from the models' export data modules. The results of LPT scenario are supplied for demonstrative purposes. Figure 2 is from the animation sub model and shows the results in a graphical form.

The data export modules supply the same information in a more formal and structured way, in terms of sheets and charts. Figures 2 and 3 are the charts that are prepared automatically in Excel to show the individual times for times part spend in system and the machining times. The machining times are grouped under 4 main values, each corresponding to a specific part type. The time in system values reach a peak value of about 300 minutes. It is not a surprising fact that the corresponding machining time for that part is only about 3 minutes which is one of the shortest values. The LPT rule forces that part to wait in the queue for a long time.

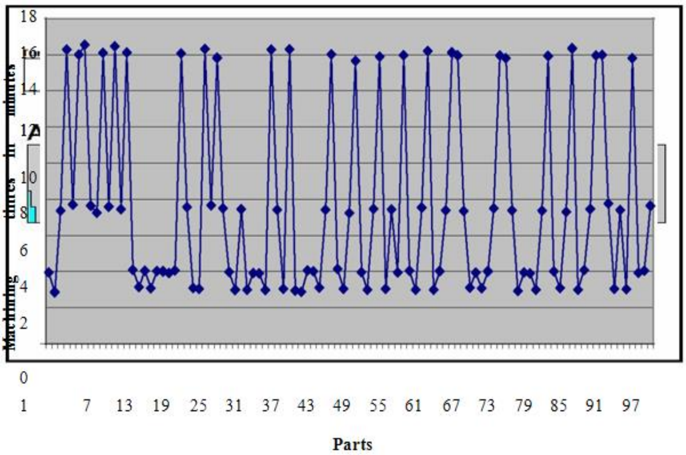

Figure 2. Machining times of parts under the LPT scenario.

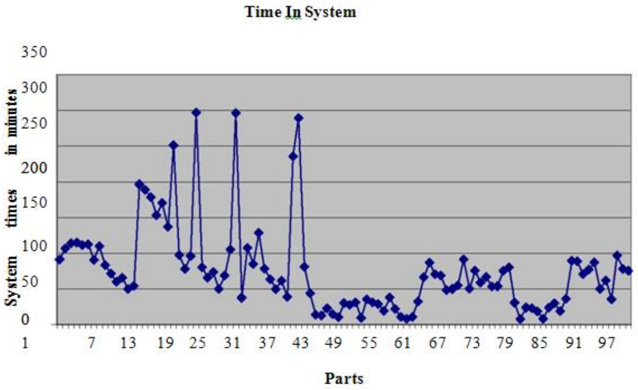

Figure 3. Time in system for parts under the LPT scenario.

Machining Times

The “simulation results” tab supplies information for all of the parts that are processed in the system in worksheets. The averages of the statistics which is important to calculate the average machining times, time parts spend in system and earliness and lateness values are also considered. The pattern of the results shows that parts of the same type are prone to be taken into the system consequently as their production times are almost the same. After the first a few parts that enter the system because of the non-existence of other types of parts, parts with longer processing times are accepted to the system. During this time the other parts that enter the system are forced to wait in the AGV queue. As an example Part no 15, with a part type of 1, enters the system at 25th minute however waits until the 220th minute for the other parts with longer processing times. Accordingly, the times those parts with shorter machining times spend in system is longer compared to parts with longer machining times.

Conclusion and Future Works

This research is mainly focused on the implementation of a flexible, re-configurable simulation and modeling system. The models developed throughout the study are used to come up with different scenarios of production and sample results and decisions about production issues that can be attained through the use of simulation are provided. Simulation is expected to increase its strength and area of application through integration with other tools. These other tools will include spreadsheets, statistical analysis software, mathematical optimizers, and programmable logic designers, robotic software, or process flow layout and analysis tools. As the final component of the study, sample simulation runs under different scenarios of production are presented. The preparation procedure of the runs and the interpretation of the results obtained through the developed software are important to provide an idea on the effective use of simulation in manufacturing systems. The scope of the paper comprises both a modeling and application approach. It provides guidelines on the determination of modeling parameters for FMS and integration of the models with other programs.

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