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SIMULATION BASED DESIGN FOR A SHIPYARD MANUFACTURING PROCESS

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ABSTRACT

Discrete event simulation can be used for virtual prototyping of new manufacturing facilities. Models built for this purpose must be easy to use, flexible, and provide a realistic graphical view of the proposed system. The DESTINY project has developed models of plate processing operations to assist shipyards in modernizing their plate fabrication lines. Configuration information for a proposed line is collected via a Web interface, which then launches a program to build and execute a simulation of the system. Graphics images and statistical reports are then returned to the user via the Web interface. The approach allows rapid analysis of technology improvements and a visualization of proposed system operation.

1 INTRODUCTION

In order for shipyards to be competitive in the future, they need to insert manufacturing technology commensurate with their product lines. Today, extensive justifications based on experienced personnel or managers willing to make risk investments are the only mechanisms for investing in new manufacturing technology. However, through the use of discrete event simulation, shipyard management will be able to make informed, quantifiable decisions regarding the amount of savings new manufacturing technology will be able to provide.

Discrete event simulation has seen limited use in shipyards, but barriers still exist. These include the need for specialized simulation modeling expertise, the length of time required to construct models, and the lack of detailed performance data on new manufacturing technologies. In addition, there is a need for CAD level process visualization; shipyards are using CAD tools to create virtual mockups of their products and expect similar quality graphics from process models.

Penn State University and Electric Boat Corporation are collaborating on a project to develop and share models of shipyard manufacturing technologies. The DESTINY project couples discrete event simulation technology, modern visualization techniques, and World Wide Web technologies to provide a “virtual prototyping” environment for manufacturing process design and modernization. The application area selected to demonstrate the approach is plate processing. Many commonalities exist among shipyards in plate processing activities, and there are significant opportunities for technology modernization and cost reduction in this area.

Specific goals for the simulation were that it be user-configurable via a Web interface, that it use a commercially available simulation language, and that it produce realistic graphics, including 3D solid components with kinematic features. Donald et al. (1999) identify some requirements for use of simulation in the design process, including the importance of visualization and the need for model flexibility.

The model is intended for use at the concept definition stage of system design, as described by Fox and Halladin (1991). The purpose of the model is to allow rapid evaluation of capacity and throughput for alternative configurations, equipment choices, and operating conditions at an early stage in the design process. Additionally, as noted by Fox and Halladin, such a model can be used to illustrate the dynamic performance of the system and as a communication tool.

2 SIMULATION METHODOLOGY

To provide the required configuration flexibility, the simulation was constructed as a set of modules. A module was defined for each of the major components in a plate processing line: predry, blast, paint, CNC marking, single gantry cutter, dual gantry cutter, kit/scrap, and overhead crane. An additional module is used for plate creation. Each module contains graphics, logic, and kinematics where appropriate. The modular approach is beneficial for reconfigurable simulations (Takakuwa and Fujii 1999).

The implementation uses Deneb's Quest language, with each module constructed as a separate simulation model.

The major difficulty in constructing the modules was to provide realistic graphics and animation, while still supporting user configurability. We illustrate this issue by discussing two cases: modeling of the overhead crane and layout of the system components.

The behavior of an overhead crane can be approximated using bi-directional track and an AGV with instantaneous rotation speed. However, realism in graphics requires that the crane be able to move in two (or three) axes simultaneously, with additional third axis movement for pickup and putdown of plates. Since Quest lacks specific constructs for overhead cranes, the crane was modeled as a machine and represented graphically as a kinematic device. Such a device uses "scripts" (sequences of joint positions) to perform movements. Modeling the crane as a machine required complex user-written logic for decision making, including what plate to move next and where a plate should be deposited (this latter issue is particularly important when the model includes multiple cutters with different capabilities and limited capacity buffers). Because of limited capacity at each operation, careful attention to deadlock prevention is required: a plate cannot be released to the crane until downstream capacity is available. Of course, the same issues arise in modeling the crane as an AGV; however the language contains specific AGV constructs to simplify development of the logic. One further issue when modeling the crane as a machine is correct treatment of empty travel. This was accomplished by defining a home position to which the crane returned after each task; this assumption reduces the number of scripts required for crane movement and eliminates the need to track current crane position.

Layout of the system components was accomplished by defining the start point of each module at world coordinates (0,0,0). Each module is translated to an appropriate location when it is included in a model. Since the user specifies the distance between operations, the modules could have been placed accordingly. However, this complicates development of the crane movement scripts, requiring that they be generated dynamically as the model runs. Further, if the distances are large, an overall view of the system is mostly empty space with very small (and virtually indistinguishable) machines. Therefore, the modules were placed with a predefined amount of empty space between them, such that the overall view of the system contained sufficient detail. The user-specified distances were used only to compute travel time for the crane. This also allowed predefinition of all the kinematic scripts for the crane device.

A second issue in modeling was to provide the user with some flexibility in describing the plate characteristics, and in defining decision rules for routing the plates to specific cutters. The model reads a user-provided list of plates to be processed which specifies plate length, thickness, material, number of pieces to be cut, length of cut, and similar characteristics. This list can come from historical data, or can be created using a spreadsheet with macros that randomly generates plates according to user-specified parameters. Decision rules for cutters were implemented by allowing input of material preference and maximum plate thickness for each cutter. When a new plate entity is generated, it determines a list of feasible cutters based on these preferences. When the plate is routed to a cutter, it goes to the first available feasible cutter, or to the emptiest buffer for a feasible cutter.

Flexibility may also be achieved by building models at several levels of detail. Bruzzone, Giribone and Revetria (1999) describe a web-based implementation of this approach for modeling shipping terminal operations. Since the plate-fabrication model is intended for use in the concept design stage, multiple levels of detail were not required.

3 WEB INTERFACE AND MODEL EXECUTION

Lorenz et al. (1997) describe several approaches for creating a web-based simulation environment. One of these is "remote simulation and animation", in which the model is built using an existing simulation language, and a web interface collects data and transmits results to the user. This is the method utilized for the plate fabrication simulation model.

The web interface, Distributed Intensive Computing Environment (DICE), was developed at the Applied Research Laboratory at Penn State to support simulation-based design. DICE is responsible for several functions in the present application. It manages user profiles, including access to modules for various design tasks. It supports interactive collection of parameters to describe the system to be simulated and uploading of a plate description file. It delivers information to the computer responsible for running the simulation application and launches the application. It retrieves simulation output, notifies the user via email that the output is available, and allows the user to download the output results.

System configuration and operation parameters are collected interactively using DICE. System configuration information includes which treatment operations are used, if CNC marking is used, the number and type of cutters used, and the distance between operations. Operation parameters include speeds, setup times, cutter preference information, etc.

The information collected by DICE is provided as a set of key:value pairs to a parser developed for this application. The parser also has access to a collection of predefined templates for building and executing the model. The parser reads the key:value pairs, conditionally includes certain templates based on the values of some keys, and substitutes other values into the templates as indicated by the presence of a key.

The templates were written in Deneb's Batch Control Language (BCL). BCL replicates many (but not all) of the operations which can be performed with the Quest user interface. BCL is used to read in the models required to represent the user's plate fabrication line, translate them to appropriate locations in the world, assign attributes to the various machines, connect the machines together logically, run the model, and produce graphical output. These instructions are contained in the templates used by the parser. The parser produces a complete BCL program; Quest is then invoked with this BCL program to build and run the model. Figure 1 shows one such model, containing predry, blast, and paint treatment operations, CNC marking, 4 cutters with their buffers, a kitting table and scrap cart for the cut pieces and unused material, and an overhead crane. The treatment operations are conveyorized; all other movement is via the crane.

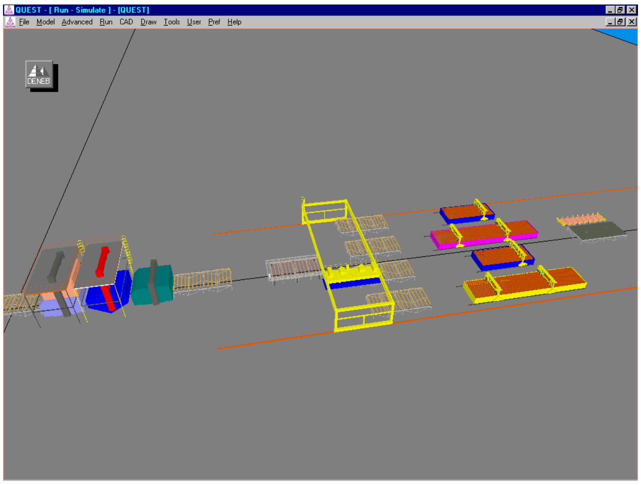

Figure 1: Plate Fabrication Line Model

After the model is built, a single run is made. One run is sufficient because the model is entirely deterministic. The only source of randomness is the plate characteristics, which are external to the model since they are contained in the plate description file. If desired, a user may generate several plate description files using the spreadsheet macro (values are uniformly distributed between user-specified minimum and maximum values), and then run these files with the same model.

The model runs until all plates in the file have been processed. The user may choose to run using scheduled release dates for each plate, or releasing each plate as soon as space is available. A summary report provides statistics on utilization of all the components and flowtime for the plates, as well as total model run time to complete all plates. If the specified cutter preferences for material type and thickness result in the inability to process certain plates, a list of plates not processed is also produced.

One of the goals of the project was to produce a high-quality animation of the simulated system. The original plan was to produce an AVI video of the system in operation. Quest provides the capability to capture frames in AVI format when the model is running. Unfortunately, user interaction is required to do a video capture. This limitation meant that we could not produce AVI video.

Quest also allows capture of screen shots in JPEG and compressed TIFF formats. This can be done using BCL commands without any user interaction. Since BCL commands can be executed while the model is running (by calling them from model logic procedures), we produced a series of screen shots by executing a loop which ran the model for a short period of time, then issued a BCL command to save the screen image in JPEG format. The resulting screen images can be viewed in sequence using a viewing program with slide show capability.

4 SUMMARY

The DESTINY project combines visualization, discrete event simulation, and World Wide Web technologies. It allows shipyard personnel to rapidly evaluate the effect of new technologies for plate processing. A model is configured by making a series of selections on a web page. The simulation is then automatically built and executed, and results are returned to the user via the web.

This approach provides a number of benefits to a shipyard considering technology modernization:

- Provide for the rapid insertion of manufacturing technologies by providing quantifiable justification for capital improvements.
- Involve shipyard manufacturing personnel with the introduction of new manufacturing technologies in a way that permits their direct input.
- Demonstrate the effectiveness of plate processing savings.

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