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Cover story:

Benefits of animation in the simulation of a machining and assembly line

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INTRODUCTION

The use of animation as a simulation tool has grown rapidly in the past few years. While animation is often seen as mainly an aid to presentation, we have found it enhances *all* stages of model development. We see benefits in three areas:

(1) Benefits for the model builder

(2) Benefits of communication between model builder and model users

(3) Benefits in presentation to users and management.

For the model builder, animation is a productivity tool which speeds the process of locating and removing errors in the model. While correct functioning of an animation does not imply the complete verification of the underlying model, many of the errors in a model will signal their presence by grossly inappropriate behavior of the animation. Animation does not eliminate the need for manual checking of calculations or for statistical verification methods, but it does serve as an important productivity tool for augmenting these methods.

Perhaps the greatest asset of animation is the increased communication it allows between the model builder and the model user. Because of this communication, the model user can be much more actively involved throughout the model development cycle than is possible without the animation. This leads to significant improvements in the model and in the benefits the user receives from it.

Combining increased user involvement during development with the advantages of animation for the presentation of model results produces a critically important benefit: An increased credibility with model users and management, and an increase in their appreciation of the value of the simulation.

These benefits are illustrated by specific examples which occurred during the development of a model of an automotive machining and assembly line.

SOFTWARE SERVICES CORPORATIONS

Software Services Corporations (SSC) is a provider of high-quality software and programming services to the manufacturing industry. To meet the growing demand for simulation and graphic modeling, SSC has formed an Industrial Simulation Group. This group offers clients simulation, modeling and support services for capacity planning, facility layout, material handling, line loading, system integration, workcell design and robot simulation.

For companies wishing to obtain models for their in-house use, SSC develops and delivers a custom model of their existing or proposed manufacturing system, and trains the client to work with the model. This approach leaves the client with the training and tools needed to analyze their existing or proposed system, and to evaluate the effects of proposed modifications.

Process description

In the example used here, SSC developed a model of an automotive manufacturing plant which machines and assembles water pumps, engine front covers and oil pumps. The plant producing these three components contains 2,500′ of power and free conveyor line, 18 double-grip robots and 5 manual load/unload stations. Located within the conveyor loops are several machining cells for raw castings. Figures 1 and 2, which are pictures of the actual animation used, show this layout.

The conveyor system consists of several closed loops positioned near each other. The manual loading stations are located next to the raw casting inventory, and the unloading stations are next to the shipping stations. In between these stations are 8 machining cells, serviced by a total of 18 robots.

Pallets carrying parts travel along a conveyor loop to a robot station. A double gripper robot picks up a new part from a pallet with one gripper, removes a completed part from the machining cell with the other gripper, places the new part in the machining cell, and places the machined part on an outgoing pallet. Other robots pick a machined

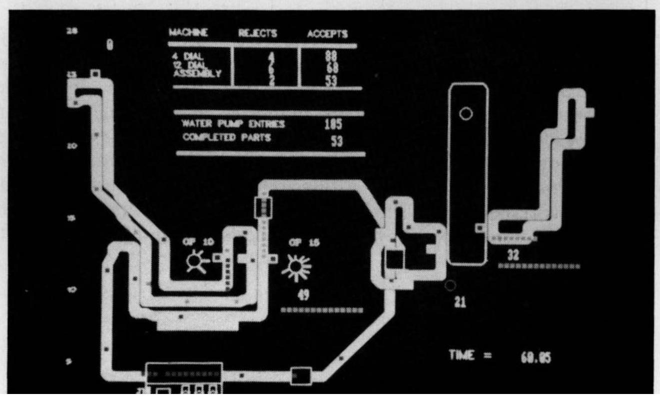

Figure 1. Water pump machining and assembly line.

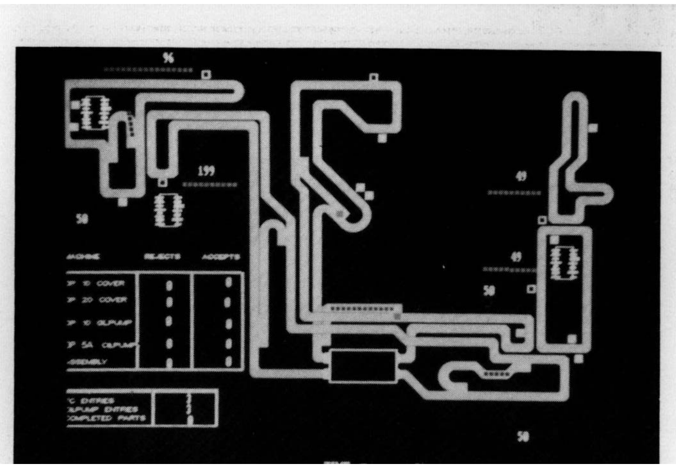

Figure 2. Engine front cover and oil pump machining and assembly line.

part from a pallet, release the pallet, and place the part on a pallet on the next conveyor loop for the next machining step. The pallets thus remain on the same conveyor loops while the parts are transferred through the system.

Since each of the many machine tools has the potential to break down and stop the entire line, the design includes several Work-In-Progress (WIP) stations for the storage of partially manufactured parts. Each WIP station holds parts which have been processed by machining stations "upstream," or prior to it. When a machine upstream from a WIP station breaks down, pallets are released from a storage spur, loaded with parts from the WIP station already processed by the upstream machines, and fed to the machining cells downstream from the WIP station. On the other hand, when a machine downstream from a WIP station breaks down, the parts arriving at the WIP station are unloaded and stored there. This scheme allows production to continue while the faulty machines are repaired.

Setting the stage for simulation

Prior to requesting the simulation, the client had designed the production system, ordered the components and was awaiting their arrival and installation. The robotic workcells which were designed for 200 jobs per hour required that the incoming workpieces be aligned in a precise and consistent fashion on the pallets. Because of this, the pallets had to be precision machined, and were thus expensive to produce. A basic question facing the plant engineers was how many pallets were required to achieve the design throughput. Over-purchasing would result in a very expensive pallet surplus, while under-purchasing would hinder the flow along the conveyor and result in daily requirements not being met.

The basic pallet question led to considering what other system parameters were related to the number of pallets. Auxiliary questions arose, such as: Should we use fewer pallets but speed up certain sections of the conveyor? Should we use fewer pallets but re-program the robots to move faster? Should we decrease machining cell time? How many extra pallets are needed for WIP stations when machines go down? What is the system's sensitivity to changes in these parameters?

To get the best handle on this situation, the client decided to have SSC build an animated discrete model, and then use it to perform the analysis necessary to answer the questions raised during the design process.

Benefits for the model builder

SSC developed the model using the SIMAN™ language and the CINEMA™ animation system from Systems Modeling Corporation. With the SIMAN/CINEMA™ system, the animation is separate from the code of the underlying model, and piggy-backs on it. It is thus possible to build the complete code for the model before doing any animation. At SSC, however, we begin a simplified animation of the model at the earliest stage of code writing because of the animation's usefulness in debugging the model. As the model becomes more complete during the coding process, the animation is enhanced and is used as an aid for model verification throughout. Three examples illustrate this point.

(1) The activity of the multiple robots in each workcell in this model must be carefully synchronized. Proper synchronization is prone to error and is difficult to verify through the code alone, but is immediately apparent from the animation.

(2) By watching the pallets travel through various conveyor loops during animation, the overall routing logic is easy to follow. Animation is of particular help in this area when trying to follow complex alternate routings due to machine downtimes. Upon machine failure, for example, extra pallets are released from bypass storage to feed the WIP station and the assembly line below it. Alternate pallet routing is one of several things this requires. Animation of this process is invaluable in checking proper triggering and response to such contingent operations.

(3) By displaying the model's statistics simultaneously with the animated plant operation, the model builder's understanding of the statistics are greatly enhanced, and incorrect formulation of statistics are easily caught.

Communication benefits of animation

The greatest benefit to SSC as a model developer is increased communication and understanding between the model builder and the model user.

As part of the normal development cycle of a simulation project, SSC produces a detailed simulation specification which describes the operational features to be modeled, the modeling approach to be taken, underlying assumptions, the data required for the model and the alternatives to be investigated. This document is approved by the model user and is the basis for construction of the model. For the machining and assembly line discussed here, this document was thirty pages long.

While it is a necessary part of a simulation project, this specification document is boring and unfriendly to the plant engineer who is the model user. Without extensive study, it is difficult to understand from the document how various parts of the system interact. Although it is relatively easy to detect inappropriate process descriptions, it is much harder to detect missing descriptions and missing details of necessary system elements. Without an animation capability, therefore, it is very hard to engage the typical model user in a meaningful dialogue over specification documents, technical descriptions and preliminary statistical results while the model is under development. Failure to maintain an ongoing productive information exchange during model development leads to misunderstanding and miscommunication about model assumptions. These are detected, if at all, only in the final stages of the project. At that point they are costly to repair, discouraging, and damaging to the credibility of the process.

Animation developed in conjunction with model coding solves this problem. With high-resolution animation, the model user has a graphic depiction of his plant which makes sense to him. The operations and logic described in the specifications become animated elements whose path through the system can be easily followed, and the interaction of pieces of the system can be directly observed. Our typical model user becomes eagerly and actively involved in periodic reviews of the model under development. In the machining and assembly line project, weekly progress reviews were held with the model users. Animation was the key to making this possible without undue burden to either party. Missing or inappropriate elements of the specification which escaped detection during the design review were found and corrected early during model development.

Animation is also invaluable in communicating the nature of design flaws detected by the analyst that need to be resolved by plant engineers.

In the machining and assembly simulation, the initial location of the bypass storage mechanism made it impossible to carry out the prescribed operations due to a complex and previously hidden interaction with other parts of the system. The animation provided a mechanism by which the problem was communicated to and understood by the model user in literally a minute. Similar problems with non-animated simulations have required hours or even days to explain. The user was able to make a timely design change. Other examples of this type occurred on a regular basis throughout the project.

Both the model builder and the model user typically will determine, by watching the animation, those features of the model which need to be enhanced and those additional "what-if" cases to be investigated. This happens much earlier in the development cycle than it would with a non-animated model. The animation of the model even becomes a focus by which several of the model users discuss design issues among themselves.

The net result is that the model user becomes an interested, integral part of the model development effort, and the credibility of simulation as a meaningful and useful tool is greatly enhanced.

The animation does not obviate the need for careful statistical analysis of modeling experiments, but it brings us more quickly to the analysis portion of the project, and we arrive at this point with a model user who truly understands the model and its limitations.

Benefits during presentation

The most recognized value of animation is in presentations to management. The presentation of a simulation analysis and its statistical results is enhanced immeasurably when graphics and animation illustrate the findings. Animation makes lively and accessible what would otherwise be a dry and somewhat obscure presentation of tables and figures.

The animation, with a proper synopsis, covers in a short amount of presentation time what would require thirty to forty pages of written explanation.

The user is left with the feeling that he has been presented with something he *can* believe in rather than something he *should* believe in. The animation enhances the feeling it is beneficial, after all, to "try before you buy."

With the use of animation as a tool to enhance the accessibility and credibility of a simulation study, simulation will more rapidly grow as a valuable, an accepted and, ultimately, as a standard methodology for the manufacturing engineer.

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