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USING EMULATION TO ENHANCE SIMULATION

Christy Starner
Mati Chessin

E2M, Inc.
System Analytics
3300 Breckinridge Blvd, Ste 100
Duluth, GA 30096, USA

ABSTRACT

Simulation is a powerful tool for examining a system or process, but ensuring that the model truly represents the real world is difficult. It can also be challenging to ensure a return on the investment put into developing a model. Emulation satisfies both problems. In an emulation, models of production lines are connected to and controlled by the actual controls that run the line on the factory floor. By doing this, the logic of the line is debugged much earlier in the process than normal, which provides myriad advantages. The model will more accurately represent the real world and any work that is being done on the line - starting up a new line, improving production, changing machines - can be tested in a virtual setting to ensure functionality and improve upon safety and cost. Emulation can reduce the costs of starting or modifying a line by up to 50%.

1 INTRODUCTION

Simulation is a powerful tool that can reveal to a project team much useful information about a system. For production lines, it can provide invaluable data to predict line performance, identify bottlenecks, test solutions, and otherwise learn about the line. Usually a great deal of attention and detail has gone into the design of the line. Historically, this has often been sufficient, but sometimes the line may not run exactly as planned. It's impossible to know if a simulation will help identify problems on the line or if it will only serve to verify that the system will work as planned. If the system is properly designed, a simulation model can still help the project team learn about it, but the value is diminished. Alternately, identifying a problem early enough to fix it can be extremely valuable. These factors can make it difficult to justify simulation.

Simulations are a powerful tool, but sometimes they are done with little return on the investment. Often businesses struggle with the decision to complete a model of a line because the return isn't guaranteed. With some exceptions, there's no way to know if a model is vital to the project's success or not. One of the chief struggles facing simulation has been making modeling indispensable to projects. The value of the model may be difficult to quantify. This paper discusses how E2M has been able to increase the value and longevity of the model and leverage its use during many phases of the project by transforming simulation models into emulation models.

2 TERMINOLOGY

For the purposes of this paper, the theoretical system that is being modeled will be a manufacturing line. E2M operates in the realm of consumer products, including food, beverage, personal care, household items, pharmaceutical, electronics, and other products. Our models are usually of the production lines, distribution systems, or warehouses for these products.

In this sphere, the term "simulation" indicates a model created of one of these packaging lines, distribution systems, or warehouses. A simulation is self-contained; all logic that controls the model is enclosed within it and is written by the simulation programmer. A simulation is intended to be run to collect data and answer questions about the system being modeled.

An emulation is similar to a simulation, but the model is controlled by logic written in a Programmable Logic Controller (PLC) by another engineer, usually an electrical engineer. PLCs are devices that are used to run and control the actual manufacturing systems that are being modeled. The simulation programmer writes logic that will write data to and read commands from the PLC, but the PLC logic is actually controlling the line. An emulation is intended to be used to test and debug the actual control code that will run the real-world system.

3 SIMULATION IN THE DESIGN PHASE

The early part of a project is an excellent time to create a simulation model. There are many levels of simulation, from very conceptual block layouts or flowcharts to detailed conveyor and device layouts. A flowchart simulation can be very useful to drive design decisions and compare options quickly and effectively. However, this type of simulation is generally not detailed enough to be utilized as an emulation.

Once the designs have been narrowed to only a few choices, detailed simulation models become more effective as selection and comparison tools. A detailed layout is imported into the simulation software and the model is built on top of the layout to ensure dimensional accuracy. Once the conveyors have been created in the model and the devices have been laid out, the simulation programmer creates the logic that controls the model and the testing phase can begin. The detailed simulation is used to test many different aspects of the system. For our customers, the most important question is almost always about throughput – can this system handle the rates it will need to run in the future? Other important factors under examination may be the impact of the failure rates for the various machines, the amount of accumulation required to buffer these downtimes, the speeds required to achieve the throughput goals, and the operational methodology to be used to run the system. All of these factors are manipulated within the model and the results of these changes are measured and graphed to provide comparison data and drive the project team in decision-making.

It is very rare for a system to be modeled and for no problems to be found, but sometimes the magnitude of the problems discovered may not justify the modeling effort and expense. In this case, planning to repurpose the model as an emulation will provide additional value to the modeling effort.

4 EMULATION IN THE EXECUTION PHASE

In the past, after the design phase was complete and the decisions had been made, the simulation typically disappeared from the project methodology. However, the power of using emulation will extend the usefulness of the simulation. During the execution phase of a project for a new material handling or production line, the controls engineer must write new control logic to operate the system. Without emulation, she won't be able to test her code until installation is complete and she loads it onto the line PLC. Even then, testing happens with the real system, where it can be hard to gather the information necessary to debug the code. Devices may be out of reach or far apart, and it may be difficult to see or hear key elements over the ambient noises and distractions on the factory floor. Additionally, time is at a premium, as service technicians are only scheduled to be onsite for so long, and the manufacturer is eager for production. If the project uses emulation instead, the controls engineer can debug code in parallel with the installation process and avoid these hassles. For this reason, emulation has the ability to facilitate rapid start-up of the line.

By moving the debug process from the factory floor to the office, emulation saves valuable time and money in many ways. The most basic is that the logic can be written and fully tested earlier in the project. The debugging effort happens in the office using virtual machines and resources rather than on the factory floor using costly equipment and supplies. The PLC programmer is able to fully test his or her logic while the line is being built. If new issues are discovered that were not uncovered in the simulation, it may be possible to make quicker, easier, more cost-effective changes to the line than if the issues were discovered while trying to start-up the line. After debugging the code through emulation, the PLC program usually arrives on-site nearly complete, mimimizing the time spent waiting for product by the technicians.

Starting up a line faster and earlier enables production to start sooner. The sooner a production line is producing saleable product, the better for the project team and the customer. Using this method has been shown to reduce time spent starting up a system by up to 50%. The savings could equal weeks of time devoted to production rather than to building and debugging the line.

5 NEW SYSTEM EMULATION CASE STUDY

One example of an emulation helping save time and money came on a recent project. The line in question was designed with a reject station just after the filling machine. If a case was not closed properly, a photoeye at the reject station would detect the open flap and trigger a pusher to push the case onto another conveyor for inspection. After passing the reject station, the product would continue through accumulation conveyor to a palletizer.

While debugging the PLC control code using the emulation, it was discovered that any time a reject was detected, the line would have to stop the filler in order to give the pusher enough time to extend, push the case off the line, and then retract. In any filling line, it is critical to not stop the filler – if the filler is not filling, the line is losing production. Using the emulation model, the PLC programmer was able to test many different scenarios to see if the line design could work. Some parameters that were examined were the time the pusher took to extend and retract and the conveyor speeds surrounding the reject station. It became apparent that the reject station would not work without shutting down the filler.

The next step was to examine possible changes in the design. The equipment had a long lead time and had already been delivered to the customer, so making what was already ordered work was important. It was determined that a bit of accumulating conveyor before the reject would solve the problem as it would provide a buffer between the filler and the reject station. In the model, the reject station was moved down the line after the accumulation section (see figure 1). The model was used to verify that the reject station would no longer shut down the filler. Although the equipment had been delivered, it hadn't been bolted in yet, so a simple design change was easily implemented.

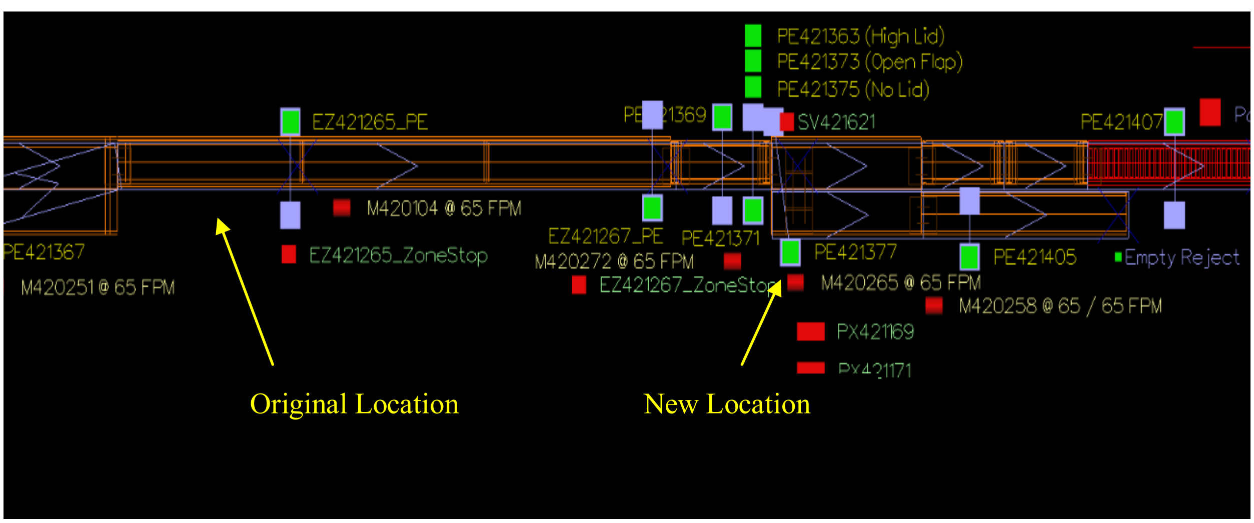

Figure 1: Original and New Locations for the Reject Station

If an emulation had not been completed in this model, the conveyors would have been installed in a way that would not work. The PLC programmer would have been forced to contemplate this problem in a high-pressure situation. It is most likely that the reject station would have been pulled out and a new, much faster, higher-cost reject station would have been ordered to replace it unnecessarily. During the time that new reject station was being built, the line would have performed poorly.

By creating the emulation, E2M was able to save both time and money during the start-up of this line.

6 CONTINUING MODELING EFFORTS

Even after the line is built and running, the simulation and emulation models of the line continue to be useful. Maintaining these models and keeping them accurate to the real-world line provides a virtual, off-line system for future testing. If machines need to be updated or replaced, improvement efforts need to be evaluated, or different products need to be tested, the simulation model can be kept as a testing ground for these changes. The emulation can be reused repeatedly to test and verify PLC changes.

In addition, both types of model are useful as training tools. The emulation model's PLC may also be connected to the operator interface for the line. New operators of the line can use the virtual system to train, eliminating the prospect of costly mistakes on the factory floor. Simulations may be used after the project to show line operation and answer questions about line performance.

7 MODELING EXISTING SYSTEMS

Although the focus of this paper has been on the use of modeling during the design and start-up of a new line, modeling is also a powerful tool to analyze and improve existing lines. An existing system can be modeled as easily as a new system. For questions about line functionality, a simulation is used to analyze the line and examine "what-if" scenarios. For issues that trace back to controls, an emulation is created and the controls may be revised or rewritten with the help of the model and a virtual start-up.

8 TECHNICAL CONSIDERATIONS

When creating a simulation that will eventually be an emulation, it is important to use a software that will support the emulation effort. Many software packages have no emulation support, or it is provided by a third party and may not be well-tested. E2M routinely uses two software packages for emulation – Emulate3D's Controls Testing software Demo3D (Emulate3D Ltd. 2010) and Applied Materials' AutoMod (Applied Materials, Inc. 2010). Both programs provide emulation support built into their framework. Other important considerations include ease of use for the end-user, who is frequently not a modeling expert, and the speed of building the system. In the experience of the authors, it is easier for non-expert users to get started with Demo3D. The software's easy-to-use, ready-made catalog items (such as conveyors, photoeyes, forklifts, and robots) enable the user to quickly get started building a system. Demo3D also uses a physics engine to more accurately model the movement of product through the system. In the authors' opinion, AutoMod is a more challenging program to start with but is also very powerful; it may be a better fit for very large, very high speed systems. The screenshot illustrating the reject station in Figure 1 is from AutoMod and a Demo3D screenshot is shown in Figure 2.

9 CONCLUSIONS

Incorporating emulation into a project can be an extremely valuable exercise. Many manufacturers recognize the value of simulation to show potential problems and test solutions early on, but without a guaranteed return the modeling effort can be hard to justify. Extending the life of the simulation by turning it into an emulation transforms the model into a valuable, multi-faceted tool that can be used over many phases of the project. Not only does emulation allow a simulation model to have multiple uses, it allows the project team to reduce start-up time by up to 50% and start getting product out the door earlier than planned.

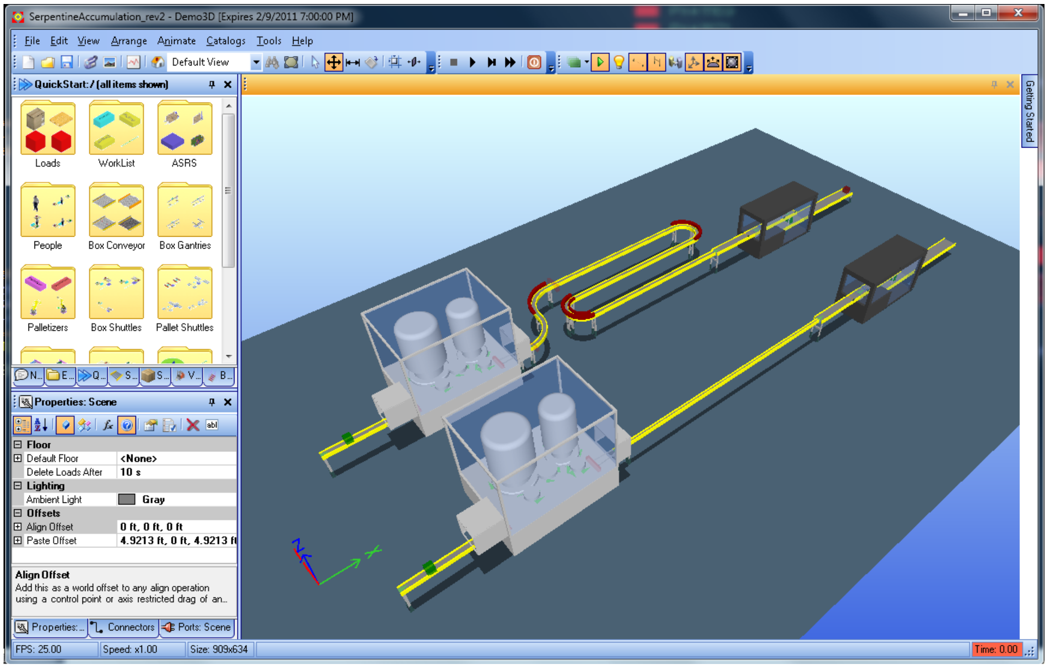

Figure 2: A Demo3D model

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AUTHOR BIOGRAPHIES

CHRISTY STARNER is a Technical Lead for the System Analytics group at E2M/Polytron, Duluth, GA. She has created simulations and emulations for over 7 years for a variety of products and production systems. She received her Bachelors of Science in Industrial and Systems Engineering from Georgia Institute of Technology and is currently completing a Masters of Science in Industrial and Systems Engineering at Georgia Institute of Technology. She is also a Certified Packaging Professional. Her email address is <cstarner@e2m.com>.

MATI CHESSIN is a Project Engineer for the System Analytics group at E2M/Polytron, Duluth, GA. For over 4 years, he has created simulation and emulation models for a variety of products and production systems. He received his Bachelors of Science and Engineering in Mechanical and Aerospace Engineering from Princeton University and his Masters of Science in Mechanical Engineering from Georgia Institute of Technology. His email address is <mchessin@e2m.com>.