Integration of modeling and simulation of a production system using generalised stochastic petri nets

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Abstract

This paper presents the experience of an on going project aiming the evaluation of a production planning system for a light metal industry (collapsible tubes). The production lines have been modelled using Generalized Stochastic Petri Nets (GSPNs). The evaluation aims at gaining acceptance of the planning procedures in practice and the increase of the consistency of decisions at both planning and scheduling levels. The ARTIFEX tool has been used in order to model, simulate and test.

Keywords

Business Modelling, Generalized Stochastic Petri Nets (GSPNs) , Simulation.

1 INTRODUCTION

The Greek market of collapsible tubes remains under the control of the big multinational companies of the cosmetics and pharmaceuticals sectors. The supplier's flexibility is an important incentive for the customers, as it makes possible for them to avoid the maintenance of important inventories, in a market characterised by instability.

The necessity to increase flexibility results in short lead times and influences the production planning and control (PPC) software. The attention is moved from the modules of the middle term production plans (MRP-CRP) towards the short term production scheduling (Womack, 1996). Scheduling problems are perfect examples of hard combinatorial optimisation problems, and from the complexity results appears that efficient algorithms exist only for a very limited class of problems.

Attention towards short term scheduling reflects also the trend towards autonomous production lines supported by distributed industrial information systems (Schonberger, 1982). Autonomous lines make the scheduling simpler but in practice priority decision rules are mainly used (FIFO, SPT, Dynamic Slack per Remaining Operation etc). As the production schedules thus developed do not optimise a priori any criterion they have to be evaluated against appropriate performance measures such as throughput rate, average utilisation of machines or work in process, in order to gain information about the efficiency of the plan. Simulation is a proven methodology that allows evaluation of production schedules, incorporating activities, resources, business rules, workload and other characteristics of a process into one model. Virtually any performance criterion can be examined with simulation, taking also into consideration the unreliability of the equipment and the setups between production lots. Since simulation models mimic the actual process' response to events happening over time, it is possible to depict reality in a reliable way.

2 PROPOSED METHODOLOGY

2.1 General concepts

Generalised Stochastic Petri Nets (GSPN) contain both immediate and stochastic transitions. They can model activities that occur almost instantly, along with processes that take a longer and random amount of time (Desrochers, 1995). The latter is useful for modelling processing, failure and repair times of individual machines thus the physical operation of the production system. They are also appropriate to model the company's production planning and control system. Once the model developed and tested it can be used to simulate the production and evaluate alternative production schedules. The planner can test aggregate capacity constraints at the lot-sizing level against the detailed schedule to avoid infeasible schedules or unnecessary delays. The accuracy of the delivery dates promised and the expected levels of the work in process can also be tested, thus increasing the confidence to the plan.

2.2 Development of the model

Two complementary models are developed, the production system model and the production planning and control model. The former is used to model the behaviour

of the components of a production system. The latter is used to model the production plan and the response of the control system to the various events. Both models are developed at different levels, ranging from major process activities to the fine details of the process. A combination of bottom-up and top-down approach is used to facilitate the modelling, taking advantage of the locality principle of Petri nets. The locality principle on states and actions (transitions) is a direct consequence of the bipartite structure of Petri nets and the marking definition. The importance of the locality principle resides in the fact that Petri net models can be locally modified, refined or made coarse, without altering the rest of the model (Peterson, 1981).

The proposed methodology begins with a bottom-up (modular) composition leading to the development of the first level model. This involves the specification of subsystems or modules for every generic production resource (machines, conveyors, buffers, maintenance team etc) and a systematic procedure for combining these modules with their interactions into an integrated system (Leopoulos, 1984). Then a top-down synthesis is used where, starting with the initial (generic) module, a final model is produced through stepwise refinements in order to include particularities of the specific resource.

In the present case study three generic modules have been used. The generic modules are simple, easy to verify and specified separately in detail. Interactions are represented by common places. At each synthesis step, these interactions are considered, and the corresponding modules are combined through merging these places to a larger subsystem. Analysis of the combined net is possible immediately after each synthesis step, so when the final stage of synthesis reached, the analysis can be simplified. At the end of the synthesis steps, the final system and some of its important properties can be obtained (Proth, 1993).

Two modules representing a particular machine and transportation system have been refined. Beginning with the generic model of the equipment, refinement is done in a stepwise manner to incorporate more detail into the model. The refinement continues until the level of detail satisfies the specification of the module. The method has the advantage of viewing the module globally from the beginning to the end of the analysis.

Figure 1 First level model of the production line.

Class: PLINE7
 Subnet: MAIN_SUBNET
 Page: PLHROFORIAKO_MODELO

Figure 1 First level model of the production line.

3 THE CASE STUDY

3.1 The company

The company under consideration operates close to Athens a full and completely specialised unit, that covers the needs of the Greek market in collapsible tubes and exports to neighbouring countries. The plant operates a slugs operation and lubrication unit, a collapsible tubes production section, a monoblock aerosol cans production section and a monoblock bottle production section.

3.2 Production planning and control function

Flexibility is an important incentive for the company's customers, mainly multinational companies of the cosmetics and pharmaceuticals sectors. As customers try to establish JIT techniques they prefer local suppliers in order to produce only when their forecasted demand becomes a firm order. In addition the company

undertakes small orders in the important markets, which the big competitors avoid in order not to disturb their production plan.

The commercial department transmits the forecasted and confirmed customer orders to the planner who develops the detailed scheduling, after checking the availability of the raw and packing materials. The production orders are grouped, in order to avoid unnecessary changeovers and the delivery date is taken to consideration. The main raw material (aluminium slugs) comes from a factory belonging to the same company, so very tight due dates are possible, the main “unpredictable” factor being the availability of the equipment.

As the production schedules are developed according to empirical rules they have to be evaluated against appropriate performance measures such as expected lead times, in order to gain confidence for the promised due dates. In addition total time of expected breakdowns for the individual equipment and stoppages of the production line is used in order to predict the necessary maintenance effort. An evaluation of the maximum number of pieces in the two buffers is also necessary as it influences the total productivity of the line.

3.3 Modelling and simulation with GSPN

The production system model describes the collapsible tube production line. The first level model is presented in Figure 1. Three generic modules, declared as objects, modelling a mono-operational unreliable machine, a buffer and a transportation system have been used in a bottom-up approach in order to model the production line. All interactions between the objects are declared through common places.

The production planning and control model corresponds to the messages coming from the sensors, using the same objects as the physical model including one additional object LINE CONTROL.

The module modelling a piece of equipment (press) as an unreliable machine is briefly presented below (Figure 2). During normal machine work, new tokens representing aluminium slugs of specific dimension enter the machine through input place IN (feeding system). The tokens pass through transitions STABILISATION, HAMMERING and DISENGAGE representing the operations transforming the slugs to tubes. Through output place OUT the tokens leave the module (the tubes proceed to the next production step). Tokens in places OK1, OK2, OK3 represent the normal function of the machine.

Class: HAMMER
 Subnet: MAIN_SUBNET
 Page: MAIN_PAGE

Figure 2 Model of an unreliable machine (Press)

When a failure occurs, transition HAMMERING cannot fire. The token from the place STABILISED is led to sub-module BREAKDOWN (Figure 3). Firing the transition FAILURE absorbs tokens OK1, OK2, OK3 “freezes” the machine and asks for a technician (output place DEMAND FOR TECHNICIAN). Once a failure has occurred, all the equipment related to the press must stop (output places INTERRUPT IN COMING, INTERRUPT OUT GOING, INTERRUPT DISK GATHERING). A technician is necessary to repair the machine (transition REPARATION). After the reparation of the machine, the related equipment may start working again.

3.4 Production plan simulation

The evolution of the marking simulates the execution of a production plan. A list of orders must be executed in sequence and every order corresponds to different products.

At regular intervals, a check on the produced quantity is performed. If the quantity is sufficient, then the production stops (sub-module PRODUCTION INTERRUPTION) and the procedure to empty the production line starts (sub-module EMPTYING PROCEDURE). When the production of an order has been completed and a new order must begin, a global change of the parameters of the model has to take place in order to introduce the features of the new product (elementary operations times, total quantity of the order etc). Place END OF ORDER receives a token from the output place CHANGE PARAMETERS (object LINE CONTROL). When a new product must be produced transition CHANGE

ORDER fires. The parameters of all the modules (machines) are changed to the ones needed for the new product and the production line is ready to start again.

Class: HAMMER
Subnet: FAILURE_INTERRUPT
Page: FAILURE

Transition CHANGE ORDER has a fire delay equal to the setup time.

Figure 3 Sub-module “Breakdown”

3.3 Evaluation of Results

The evaluation of the production plan is based on three indicators:

Lead time of the production process. This lead time affects the promised due date which is offered to the customer by the company

Total time of breakdowns for the individual equipment and stoppages of the production line. This time affects the plan of the maintenance team.

Number of pieces in the two buffers. The pieces in each buffer is a parameter that affects the reliability of the whole production line.

4 CONCLUSIONS AND FURTHER RESEARCH

The markets' requirements for products in small amounts and quick response to the demand result in very tight due dates. Production with autonomous production lines, facilitates scheduling and increases flexibility. Production schedules developed according to empirical rules have to be evaluated against appropriate performance measures in order to gain confidence to the plan. Simulation is a proven methodology that allows evaluation of production schedules, incorporating

activities, resources, business rules, workload and other characteristics of a process into one model.

Generalised Stochastic Petri Nets can model the physical operation of the production system as well as the production planning and control. Once the model developed and tested it can be directly used to simulate and evaluate alternative production schedules. In addition Petri net models can be locally modified, making bottom-up and top-down methods possible. A subject of further research is to extend this approach, by creating generic modules for the production planning system simplifying thus the simulation of alternative production rules and/or plans.

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BIOGRAPHY

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