DISCRETE EVENT SIMULATION-BASED REAL-TIME SHOP FLOOR CONTROL

Samieh Mirdamadi, Franck Fontanili and Lionel Dupont
Ecole des Mines d'Albi-Carmaux
Centre Génie Industriel
Campus Jarlard, 81013 Albi, France
E-mail: samieh.mirdamadi, franck.fontanili, lionel.dupont@enstimac.fr

KEYWORDS
Discrete Events Simulation (DES), On-Line Simulation, Shop Floor Control, Decision-Making Aid, Manufacturing Execution System (MES).

ABSTRACT

To remain competitive in increasingly changeable markets, companies need to be reactive. They must often face unforeseen events, such as a cancellation or a modification of order, taking into account rush order, random interruptions of the production system, etc. This requires, in particular, a real time Production Activity Control (PAC) in order to deal with emerging critical events. We distinguish two types of production activity control: reactive control and corrective control. Reactive control is rather intended to anticipate the disturbances, whereas corrective control intervenes following an unanticipated event. Among all the software used in industry for real time shop floor control and the decision-making aid, we are particulary interested in Discrete Eevents Simulation (DES) coupled to Manufacturing Execution System (MES). In this paper, our objective is to show the interest to use 'On-Line Simulation' for real-time production activity control. We will also detail the designed functionalities and the features of such a tool.

1. INTRODUCTION

To remain competitive, the manufacturing industries are required to improve their reactivity, both on the strategic level, to adapt to the progress of technology or to follow the market trends and on the operational level, to react to the risks. In this last case, the systems of production must thus be controlled in real time in order to react at the time of the critical drift and also to anticipate the interruptions in the future. It is the 'Reactive Control' of shop floor (Berchet, 2000). In addition, the analysis and the decision-making must have the possibility for a more precise result with a response time corresponding to the fastest possible interval of time or at least lower than the interval of time between two events.
For that purpose, one can use largely known shop floor data-processing software: process supervision, shop floor scheduling, follow-up of the equipment, etc. In this paper, we propose to use another software: the discrete events simulation (DES), seldom employed in industry for real time production activity control.
During the phase of design of a production system with a model completely disconnected and independent of the real system, one must not only describe its structure but also determine its dynamic operation. With this intention, we use the DES in order to dimension the resources, to test the control rules, etc. We then address the 'Off-Line Simulation' with a use in the re-engineering phase of an existing system or in the preparation phase of a production (Fontanili et al. 1999). We take a quick look through the applications of off-line simulation in the phases of conception, re-engineering of production activity control, in parallel with a real or virtual system.
During the exploitation phase of a production system, it is necessary to be able to react and to get involved during its operation in order to respect the anticipated planning of the job order to the best of its ability. It is to this purpose that we suggest using the 'On-Line Simulation' by use of a model supplied by data resulting from the real system in process. It is thus important to know the state of the real system, which can be recognized through the use of acquisition devices and filing of real data by coupling the production shop floor software with the MES.
In this work, after a state of the art of the advances in the field of shop floor control, we will show the interest of on-line simulation with discrete event 'DES' for reactive or corrective control. We will then approach the functional specifications of a software for control based on-line simulation.

2. PRODUCTION SHOP FLOOR CONTROL

Generally, the concept of control relates to the organization of the relations between physical sub-system and decision sub-system. Control is regarded as a whole of activities allowing short-term production in the shop floor, in agreement with the objectives established by the production control and adapting the production to the disturbances that may occur on the shop floor or its environment (Grabot et al. 1997). 'Production Activity Control' (PAC) suggested by the APICS (Apics, 2005) is the function of routing and dispatching the work to be accomplished through the production facility and of performing supplier control. PAC encompasses the principles, approaches, and techniques needed to schedule, control, measure, and evaluate the effectiveness of production operations. In the particular

Proceedings 21st European Conference on Modelling and Simulation
Ivan Zelinka, Zuzana Oplatková, Alessandra Orsoni ©ECMS 2007
ISBN 978-0-9553018-2-7 / ISBN 978-0-9553018-3-4 (CD)

case of manufacturing, 'Shop Floor Control' is a system using data from the shop floor to maintain and communicate status information on shop orders and on work centers. Shop floor control can use order control or flow control to monitor material movements through the facility. The major sub-functions of shop floor control are assigning priority of each shop order, maintaining work-in-process quantity information, conveying shop floor status information to the office, providing actual output data for capacity control purposes, providing quantity by location by shop order for work-in-process inventory and accounting purposes, and providing measurement of efficiency, utilization, and productivity of the work force and machines.
The major sub-functions for flow control are based primarily on production rates and feeding work into production to meet these planned rates, then monitoring and controlling production.
Control has to allow adaptation and optimization of the operation of a shop floor to achieve the objectives of production. To optimize it, it is necessary to follow the actions in the course of production as well as the actions finished in order to verify the efficiency or the output. The follow-up of these actions and the measurement of the output make it possible to ensure that the objectives are achieved. In addition, the control of production must enable to identify the problems, to measure the impacts of the corrections in the performance of the shop floor and to find a response satisfactory prior to the occurrence of event (Neubert, 1997).

3. TOOLS FOR DECISION-MAKING AID DURING CONTROL

The considerable development of data processing makes it possible to have tools during all the stages of the life cycle of a production system. For the design phase, there are Computer Aided Design (CAD) tools (Catia, AutoCad, SolidWorks, ProEngineer…), Computer Assisted Process Engineering (CAPE) tools more specific to the production system (Delmia, Tecnomatix…) or flow simulation tools (Witness, Arena, Promodel, Automod, eM-Plant, Quest…).
In the phase of re-engineering, it is possible to use the same tools as those applied in the design. We also have maintenance tools and DMS (Design Maintenance System).
For the exploitation phase, there are several tools adapted to the decision level and the horizon of planning: APS and ERP for the medium and long terms, operational tools for short-term scheduling. A ten years ago MES (Manufacturing Execution System) appeared, which has several functions or services more advanced than a simple supervision (see standard ISA S95). They make it possible to run and follow the manufacturing orders on the very short term and are situated between real time monitoring control with Programmable Logic Controler (PLC) and planning tools.
MES contributes to the decision-making aid thanks to real time key indicators, but does not guarantee the optimality of the decision. It is often noted that design and exploitation software tools are used separately and that there is thus no experience feedback of the exploitation towards the conception. It is particulary the case of the flow simulation and MES.
The general objective of this research is to establish a link between a simulation tool and MES, in order to bring a supplementary level in the decision-making aid for the control of a production system, while gradually refining the coherence of the model of simulation compared to the real system, thanks to the dynamic update of the data used. The principle selected is to initialize the model in a state close to the real system, starting from real data collected by MES. Then, a simulation must be released while accelerating time in order to check if the real system drifts compared to the fixed objective. In this case, other simulations can be released while intervening on the decision variables to find a solution that minimizes the drift. The best solution is then transferred towards the real system through the MES.

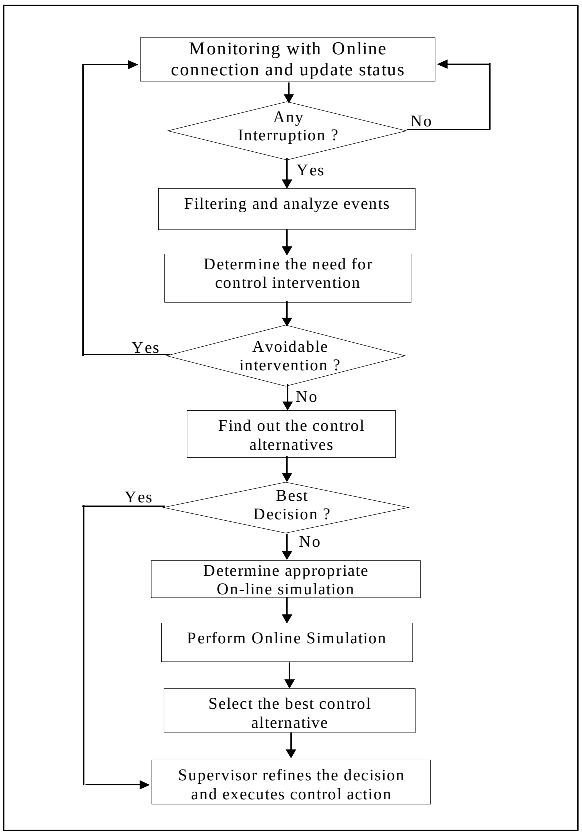

Figure 1: Principle of On-Line Simulation

4. DISCRETE EVENTS SIMULATION

Discrete events simulation is a powerful approach, which can model a real system and reproduce its dynamic behavior on a computer. Applied to a production shop floor, it allows to measure the performance and to check several scenarios with various assumptions.

We can simulate all the industrial flows (physical, informational, decision-making), on different temporal horizons (long term, average term, short term, in real time) (Bakalem et al. 1995) and in all the phases of life cycle (design, re-engineering, exploitation).
We distinguish two types of simulation according to the connection of the model with the real system: '*Off-Line Simulation*' where the model is disconnected from the real system, '*On-Line Simulation*' where the model is in direct connection with the real system.

4.1. OFF-LINE SIMULATION

Today, off-line simulation is rather widespread in manufacturing industries and the applications relating to production shop floor are numerous. It is mainly applied in the design phases and process re-engineering. We can also use it in the exploitation phase, for the preparation of the release of production. As there is no coupling between the simulation model and the real system, the simulations are released by initializing the model either in an empty and available state or in a state obtained after a warm up period. In this second case, the initial state of the model does not correspond exactly to the state of the real system at a given moment.

4.2. ON-LINE SIMULATION

On-line simulation means that it is possible to make a commitment in a simulation in progress and to validate the result of alternative simulations immediately (Becker, 2005). The objective of on-line simulation is to obtain a useable result in the real system. It is necessary thus that the decision, after the analysis of several scenarios of simulation, is precise and fast. To guarantee the precision of the decision, it is important to have a model sufficiently close to reality and containing variables associated with the state of the real system. This is the reason we need an on-line connection between the model and the physical system. As regards the speed of the decision-making, it is desirable to be able to carry out several simulations in the shortest possible time, corresponding to an interval of time included between two events detected on the real system. Rather than warm-up period, it is better to find an initialization process faster and more coherent with the state of the real system. On-line simulation is started to have a short-term projection of the real system and, if necessary, to correct the control parameters. The mechanisms of decision-making have to allow a reaction on the physical system in real time.
The Figure 2 illustrates the various types of discrete events simulation with off-line or on-line in the various phases of processes engineering.
In conclusion, although there are only very few industrial applications in the manufacturing systems, the on-line simulation appears to us to be one of the most effective tools of decision-making aid for the shop floor control. We will try to specify the functionalities waited to satisfy the need in terms of shop floor control.

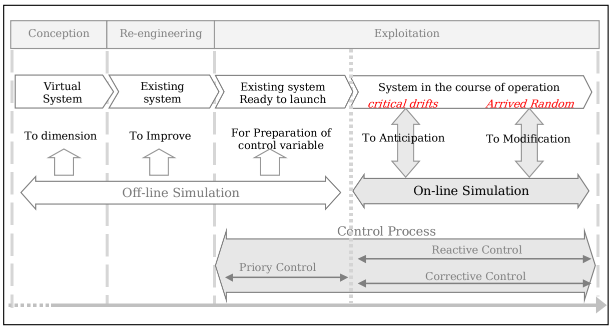

Figure 2: Different DES applications and control in production process

5. ON-LINE SIMULATION SUPPORT FOR REAL-TIME SHOP FLOOR CONTROL

The real-time control via on-line simulation in manufacturing industries can be used to identify, to better understand, to control the problems and to visualize internal functioning procedure of the shop floor in real time. It must also help anticipate the problems and look for the means of increasing the reactivity of the production system.
Control with on-line simulation makes it possible to have simulation models which correspond to the real state and thus to have a more faithful result of simulation. With this model, we are able to compress or relax the time variable for better studying the system, to identify the constraints and the disturbances like blockings, to anticipate risks, to avoid problems and to find the origins of the disturbances.

6. SOME APPLICATIONS OF DES-BASED SHOP FLOOR CONTROL

Simulation can be used to resolve the problems of on-line control (Manivannan et al. 1991) by using the method of ETS (Event-Time Synchronization). This method makes it possible to have a simulation model with the same behavior and complexity to illustrate an on-line control in front of the events. It then synchronizes the events and adjusts the times associated between the model and the shop floor. Connection of a data collection system with an emulator allows the collection of the state and the measured performance of the emulated system.
The proposal for a new architecture of KBOLS (Knowledge Based On Line Simulation) (Tayanithi et al. 1992) is to obtain better productivity and minimize the interruptions. This work takes into account only two types of interruptions: the breakdown machines and the rush orders. It does not consider the critical events before the disturbances appear. First, on-line simulation is used for analysis of the effects of the noticed interruptions and alternatives control. Second, it is used as a knowledge base to treat the interruptions. An emulator of the physical system checks the results before the application on the real system. There is the difficulty

with the response time between the modification of the control decision and the execution of current control.
The interest in having a connection between an on-line simulation model and data of the real system is the decision-making aid by studying the various scenarios at the time of occurrence of the interruptions, like the breakdown, and also to consider preventive actions (Manivannan et al. 1992).
The advantage of an 'event-driven' or 'exception approach' control via simulation when compared to periodic control is studied (Katz et al. 1993) in front of the scheduling changes caused by the interruptions, urgent orders, and drifts in the plan. This article uses the manner of reactions for decision-making after an event occurs. Reactions in front of the events or, in the case of change, the performance by report/ratio of performance envisaged is carried out in the work of Kim (Kim et al. 1994).
An application of simulation-based control to predict the date of treatment of a plan and to obtain the finished good product is presented by (Smith et al. 1996). The frequent exchanges between the model and the system are important and take into account the processing times on each station.
The use of the simulation models can support the operational planning of production, services and maintenance. This work is targeted to check the production plan, on-line supervision of the real state, and integration with the source of Planning information of ERP, MRP, etc. The authors consider integration of a tool of AI (Artificial Intelligence) to an autonomous semi system for decision support.
Decision-making supported by on-line simulation with discrete event is presented in the SRDM approach (Simulation-based Real-time Decision Making) (Hyun et al. 2006). This approach uses the traditional steps (monitoring, data-collection, simulation, decision and execution). Insufficient time is a problem to simulate each alternative rule. Artificial intelligence (AI) method is proposed to solve these problems.

7. FUNCTIONAL SPECIFICATIONS OF ON-LINE SIMULATION-BASED PAC

In spite of the interest that they present for the real-time control, the simulation tools of the market do not contain functionalities answering this need. In this section we propose, in detail, the principal conditions of implementation allowing to satisfy the need to have a tool for control containing on-line simulation.

VALIDATED SIMULATION MODEL

It is necessary yhat the model is validated and/or coherent compared to the system which it represents, to have an analysis and a specific measurement as well as a practicable decision,. In addition the model of simulation should be valid using real data. At first, validation involves verifying that the model of simulation corresponds to all the detailed levels of the model in the physical structures and the design of the real system. Then to check if the simulator carries out the model correctly. In addition the model must reflect operations of the real production well. And finally to validate the experience of simulation and obtain the results.

NEED FOR AN ON-LINE CONNECTION

Once the model is validated on the physical structures and the operation, it needs additional information to visualize the current state of the real system and better diagnosing the problems. With this connection, the entries of the environment are identical for the true system and the model (Hanisch et al. 2005).

COHERENCE BETWEEN REAL SYSTEM AND SIMULATION MODEL

The consistency of the simulation model and real system is necessary to increase the confidence of the results provided by simulation. That is, the model must have a coherent behavior with the real system.

NEED FOR THE INITIALIZATION OF THE SIMULATION MODEL

The initialization of the model is the principal problem in using on-line simulation. In the classic use of the simulation (Off-line Simulation), the simulator starts the model from an 'empty' and 'idle' state. Contrary to the case of the on-line simulation, we start a model which reproduces starting from the current state in the reality. This state of all the elements of the model (stocks, resources…) of simulation must correspond to the extracted data at the moment requested. Therefore, the variables of the system of the model must be assigned by the initial values which come from the true system. For this reason, we need to initialize the model of the simulation with the 'non-empty' state. Initialization of the model brings major problems of availability and exactitude of the data which we specify subsequently.

REQUIREMENTS OF THE DATA ACQUISITION OF THE REAL SYSTEM

An important problem to set up the on-line simulation, having needed to initialize the model of simulation, is the requirement of data collection of the real system. It requires useful information to be extracted from the physical system in the course of the operation.
To facilitate the comprehension of the terms used for this necessary information in the production, we specify some principal definitions.
Among the various systems of production, we are interested in the discrete event systems. An event is an identifiable single point in time among a set of related activities. An event corresponds to each change of the state of the components (elements) from one situation to

another, (like each arrival or exit of article in a stock) etc. Among all this collected information which represents the state of the system, we are particularly interested, in certain critical events.
These critical events are declared by the diversions on the state or in the current operation compared to the state and the planned operation.
Therefore, useful information or the data to be collected hold the critical events in order to start the simulator, and then all the events. This helps to know the state of the production system (entities, resources and activities) at the examined moment.
Generally, the useful data for the model have two characteristics: Availability and Quality (Exactitude) (Hanisch et al. 2005). Fowler and Rose (Fowler et al, 2004) specify this major problem of the availability of the active period and the correct data of the factory.
The characteristic of the availability of the data indicates, if all the data of the physical system can be determined or measured. The availability is complete when all the necessary data are present by acquisition or calculation starting from the existing data. The availabilities are incomplete if all the data necessary are neither present by acquisition nor by calculation.
The characteristic of quality describes the exactitude of the data. On the one hand, the quality of the data is dependent on the errors of acquisition and the errors of measurement. For certain applications, like the simulation of flow of traffic (Mazur et al. 2004), or the flow of pedestrians, the acquisition of necessary information is incorrect because the data are impossible or difficult to collect in these flows. On the other hand, it depends on updates, and the time difference between the initialization of the model and the time measurement.
The case completed for the approach of the on-line simulation is the combination of the available completed data and the high quality data. By reducing the frequency of the data, the model does not represent the current state of the true system.

METHODS OF REAL DATA COLLECTION

We can distinguish two ways of reaching the real data of a production system. The first way is to measure by use of detectors and the second by use of an information processing system. The accuracy of the data depends on the quality of measurement or the collection. The number of data awaited in line to be collected by the detectors is less reliable than an information processing system and it includes more errors. From another point of view, the data of a real system can be acquired automatically or manually by an operator. The method of data collection on the real system is based on the structure of its connection with the automats, protocols, networks, etc. This is the form and sequences of the way data are to be exchanged or all of the rules to be respected to receive data. Among various methods of data acquisition, there is also the acquisition using a simulation in real time like ‘virtual reality’ (Straßburger, 2005) or an ‘observant’ who know the state of the system (Cardin and Castagna, 2006).

NECESSARY SPEED FOR THE SIMULATIONS (PROBLEM OF RESPONSE TIME)

The duration of a simulation or response time relates to the number of events treated. The number of events depends on the number of objects contained in the system, on the complexity of the operation represented, and on the horizon of the simulation (Pujo et al. 2004).
In this case, the simulator has to release and obtain results including, at least, the appearances of two events on the real system. If the first simulation brings a drift of the real system compared to its objective, it is necessary to release several simulations in order to determine the values of the variables to apply the decision. In addition, according to the chosen method, the speed of initialization of the model can involve an additional increase in the duration of a simulation.

DIAGNOSING OR WAY OF FILTERING (CLASSIFICATION)

All the events that occur on the real system do not require the launching of a simulation. This information can be considered as a data base. The majority of these events are ‘normal’ and one knows in advance that they will not involve disturbances. Other similar events already appeared and were already taken into account on this occasion, which makes the launching of simulations useless, if we are able to find the treatment which had been applied. Before starting one or more simulations, it is thus important to filter and analyze the events.

8. CONCLUSION AND OUTLINE

We explained the interests of various approaches of control of a production shop floor. These shop floor controls applied in the system in the course of process production and the objective of the application of each one in the production. Our objective was to control a production shop floor in the course of operation and to have a control approach which can react in front of the events. With this objective, we proposed the integration of a tool for on-line simulation in exploitation which produces the best results in the quickest possible way. On the one hand, this approach has a reflection in front of the critical drifts compared to the planning envisaged and it is able to anticipate the risks in the system (reactive control). On the other hand, in appearance the event risks, we applied the corrective control approach in order to correct the trajectory or to modify the production objectives. To this end, the on-line simulation was applied in order to react at the time of the critical drift and also to anticipate the interruptions in the future.

REFERENCES

Apics Dictionary. 2005. *The American Production and Inventory Control Society, Inc*. Edition. No.11.

Bakalem M.; G. Habchi and A. Courtois. 1995. "PPS: a contribution for manufacturing systems simulation". *Proceedings of the SCSC'95.* Ottawa. Ontario. Canada.

Becker M. 2005. "Interactive Simulation". *inSiDE review (Innovative Supercomputing in Deutschland), The German National Supercomputing Centres HLRS, LRZ, and NIC.* (Autumn) Vol.3. No.2.

Berchet C. 2000. "Modélisation pour la simulation d'un système d'aide au pilotage industriel". Thèse. Institut National Polytechnique of Grenoble. France.

Cardin O. and P. Castagna. 2006. "Utilisation de la simulation proactive : une aide au pilotage des systèmes de production". *6e Conférence Francophone de MOdélisation et SIMulation*. MOSIM'06. Rabat. Maroc (Apr).

Fontanili F. and R. Ponsonnet. 1999. "Integration of simulation and optimization tools for the control of a multiproduct assembly line with asynchronous transfer". L'INstitut de l'Information Scientifique et Technique du CNRS.

Fowler J. W.; O. Rose. 2004. "Grand Challenges in Modeling and Simulation of Complex Manufacturing Systems". *SIMULATION* (Sep). 469 - 476.

Grabot B. and P. Huguet. 1997. "Modèles de référence et méthode orientée objet pour la conception de systèmes de pilotage d'atelier". *Le Journal Européen des Systèmes Automatisés*. Vol.31. No.1. 95-124.

Hanisch A. and T. Schulze. 2005. "Initialisation of online simulation models". *Proceeding of the 2005 Winter Simulation Conference*.

Hyun Joong Yoon and Weiming Shen. 2006. "Simulation-Based Real-Time Decision Making for Manufacturing Automation Systems". *International Journal of Manufacturing Technology and Management*. Vol.8. Nos.1/2/3. 188-202.

Katz D. and S. Manivannan. 1993. "Exception Management on Shop Floor Using Online Simulation". *Proceedings of the 1993 Winter Simulation Conference*, 888-896.

Kim M.K. and Kim Y.D. 1994. "Simulation-based real-time scheduling in a flexible manufacturing system". *Journal of Manufacturing Systems*. Vol.13. 85-93.

Manivannan S. and J. Banks. 1991. "Real-Time Control of a Manufacturing Cell Using Knowledge-Based Simulation". *In Proceedings of the 1991 Winter Simulation Conference.* 251-260.

Manivannan S. and J. Banks. 1992. "Design of a Knowledge-Based On-Line Simulation System to Control a Manufacturing Shop Floor". *IIE Transactions.* Vol.24. No.3. 72-83.

Mazur F.; R. Chrobok., S.F. Hafstein; A. Pottmeier and M. Schreckenberg. 2004. "Future of Traffic Information Online-Simulation of a Large Scale Freeway Network". *Proceedings of IADIS International Conference WWW/Internet 2004*. Vol.1. 665-672.

Neubert G. 1997. "Contribution à la spécification d'un pilotage proactif et réactif pour la gestion des aléas". PHD Thesis Project. Institut national des sciences appliquées de Lyon, Villeurbanne, France.

Pujo P.; M. Pedetti and F. Ounnar. 2004. "Pilotage Proactif des Lignes de Production KANBAN par Modélisation DEVS et Simulation Temps Réel". *4e Conférence Francophone de MOdélisation et SIMulation.* MOSIM'04. Nantes. France (Sep).

Smith J.; B. Peters ; J. Curry; G. Drake and C. La Jimodière. 1996. "Advanced Tutorial – Simulation-Based Scheduling and Control" *Proceedings of the 1996 Winter Simulation Conference*. 194-198.

Straßburger S.; T. Schult.; M. Lemessi and G.D. Rehn. 2005.
"Temporally parallel coupling of discrete simulation systems with virtual reality systems". *Proceeding of the 2005 Winter Simulation Conference*.

Tayanithi P.; S. Manivannan. and J. Banks. 1992. "A knowledge-based simulation architecture to analyse interruptions in a flexible manufacturing system". *Journal of manufacturing systems*. Vol.11. No.3. 195-214.