BEHAVIOUR-BASED PRODUCTION PROCESS CONTROL IN UNCERTAIN PRODUCTION ENVIRONMENT

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ABSTRACT

This paper focuses on disturbances handling and uncertainty management in Manufacturing Execution Systems (MES). The conception of behaviour-based shopfloor control is discussed. An attempt will be made to demonstrate the usability of behaviour-based control in the field of MES. The general state of the manufacturing process is categorized into four classes. According to the classification the appropriate action could be selected. Coupled with Cockpit Task Management BBC offers promising solution for disturbances handling in MES's.

INTRODUCTION

Production Process Management (PPM) has two distinct functional areas*:* *Production Planning* and *Production Control*. The planning and the control use different type of models, methods and tools, although the models have tight semantic relationship.

Production Planning (PP) is usually implemented as a functional component in *Enterprise Resource Planning* (ERP) application. *Supply Chain Management* (SCM) and Customer *Relation Management* (CRM) modules are very specialized areas thus they usually are implemented in ERP as additional components or applications.

Production Control is usually realized in the computer applications of Shop *Floor Control* (SFC); *Manufacturing Execution Systems* (MES) and *Quality Assurance,* (QA).

Some researchers classify the device controllers of *Manufacturing Automation* such as Computer Numerical Control, Programmable Logic Control, Robot Control, and Cell Control into Production Control. Others believe those belong to a separate control layer called *Production Activity Control,* (PAC).

Production Control includes the specialized area of short term production scheduling (*Detailed Scheduling*), which is usually a predictive pre-production activity opposed to the numerous reactive function of Production Control. Especially for very stochastic processes. Detailed Scheduling can be accomplished as a reactive or a rule-based real-time scheduler. In this case Production Control integrates scheduling activities as a part of certain global control policy.

This paper focuses on the MES level reactive activities, especially on the Production Process Management and *Uncertainties Management* (UM). This activity is also known as real time *Process Management.* In MES terminology it belongs to *Decision Making and Dispatching* function but it is also in close relationship with *Automatic Detailed Scheduling* and *Production Tracking and Monitoring.* Outside the MES it is associated with Production Planning and some aspect of the SCM system. Figure 1. depicts the role of Uncertainty Management in a Production Information System.

The difficulty of UM lies in the tight time window in which intervention can be made. The need for reducing risks and losses is higher and higher in the Customized Mass Production. The shop floor level uncertainty handling is subject of further improvements in the real time production management.

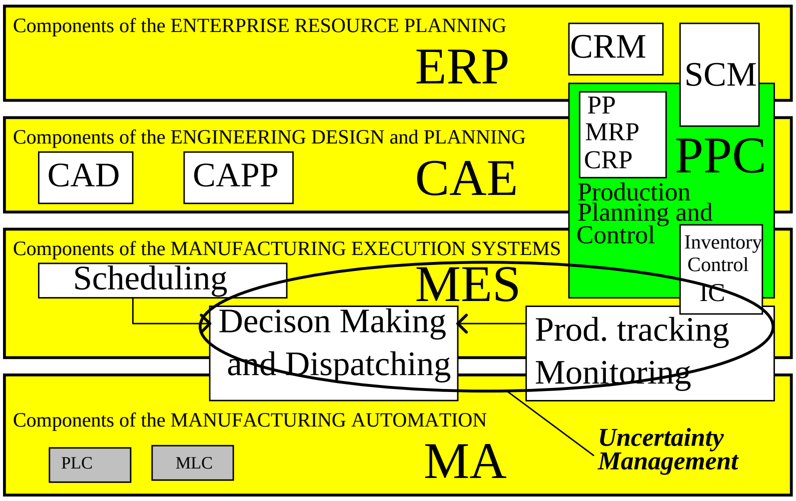

Fig 1. The context of UM in MES

THE CONCEPTION OF BEHAVIOUR-BASED SHOPFLOOR CONTROL

Real time process control initiates some modelling issues. There are some effective theoretical approaches to solve them as follows:

- Nonlinear dynamics

  The production system is a typical nonlinear dynamic system. It consists of linked local objects belonging to four major classes:

  1. Resources.
  2. Product entities.
  3. Production orders, jobs.
  4. Operations.

  The object of these classes undergoes state transformations thus evolving as time passes by. The manufacturing process is non-linear resulting nearly impossible to predict global states due to its stochastic nature. The whole system has tendency to produce chaotic, bifurcated phenomena or bottle-neck problems.
- Situation theory

  Situation theory models the possible state transactions of complex systems and the possible (allowed) interactions to change state variables of the system. Situation theory allows the global characteristics of state transactions to be assessed. Production systems have some widely used performance indicators to measure (e.g.: the indicators of *production triangle* [16]). However, those indicators themselves are not enough to improve these processes.

- Cognitive agent architecture
  Cognitive agent architecture based model offers promising solutions for real-time production control in multi-agent context.
- Adaptive intelligent systems
  Adaptive intelligent systems theory supports conformability to uncertain environment. The adaptively can be implemented in numerous ways.
- Emergent synthesis
  Emergent synthesis is a new effective approach to design the control of complex, non-linear system working in uncertain environment.
- Behaviour-Based Control
  BBC is a possible way to control complex, non-linear systems. Initially, the technique was used for programming intelligent robots. In BBC various control algorithms can be used depending on the goal of the process and the unpredictable interaction with the environment.
- Cockpit Task Management
  Controlling complex systems often requires combining automatic control with human interactions. For example see flight control: the planes are controlled by the pilot, however the majority of the flight is controlled by robots. In this kind of hybrid control the computer visualization plays important role. In the user screen the right information is shown which is the most effective in supporting the required behaviour of the controlled system. In jargon the user screen is called cockpit. Table 1. Summarizes some characteristics of the control methods and their relationship. The control tasks belong to dynamic setpoints and disturbances (coming from the uncertain environment). CTM involves the following sub tasks:
  1. Task initiation: The initiation of tasks when appropriate conditions exist.
  2. Task monitoring: The assessment of task progress and status.
  3. Task prioritization: The assignment of priorities to tasks relative to their importance and urgency for the safe completion of the mission. Resource allocation: The assignment of human and machine resources to tasks so that they may be completed.
  5. Task interruption: The temporary suspension of lower priority tasks so that resources may be allocated to higher priority tasks.
  6. Task resumption: The resumption of interrupted tasks when priorities change or resources become available.
  7. Task termination: The termination of tasks that have been completed, that cannot be completed, or that are no longer relevant.[8]

Table 1

	Predictive Scheduled	Proactive	Reactive CTM	Adaptive BBC	Learning
The model	Known, deterministic	Stochastic	Known	Incomplete Partially missing	Unknown
The goal	Known, defined	Defined	Changes quickly	Predicatively changing	Abstract goal
Example	Following a schedule, path generation	Stabilization	Following changing goals	Real time disturbance handling	to survive

THE FUNDAMENTS OF BEHAVIOUR BASED PRODUCTION MANAGEMENT

The following section deals with a possible way of uncertainty management of production processes as follows: the model of the practical (multi task, multiple resources) problems is non-linear. Processes can be characterised by internal relationships and external constraints. The jobs follow each other in sequence and have limited technological intensity. This may result bottlenecks, unstable states, unwanted delays of the tasks.

The production processes are assessed by certain *process indicators*. The primary goal of a production process is to satisfy production orders under the specified constraints. The goal can be met at different cost and time. The performance indicators are depending on predictive planning, scheduling and allocations. Systems working close to overload have the tendency to have bottlenecks and critical processes. These systems may behave chaotically, i.e. a small change in the scheduling may result dramatic change of the performance indicators. The stochastic events increase the tendency for the deviation of the planned states. The disturbances are often impossible to avoid. The most common sources of disturbances are as follows:

- Tool breakage, interruption of operations.
- Machine breakdown, outage of resources.
- High rejects rate.
- Unexpectedly low production intensity.
- Human errors.
- Material problem, supply chain delays.
- Long set-up times.
- Outage of labour-power.
- High rate of demands.
- Change of the priority of the jobs.
- Appearance of urgent jobs.

The aim of uncertainty handling at the MES level is as follows:

1. Develop performance indicators from the local data which allows the global state of whole system to be assessed.
2. Identify the most important situations based on the global indicators.
3. Classify the situations into appropriate number of classes to allow interactions to be done in real time.
4. Assess the state of the production and make decision on the behaviour of production control. This defines a Behaviour-Based Control whose interactions are assigned to behaviour classes.
5. Select the appropriate actions based on the selected behaviour. The possible actions and their parameters should be modelled beforehand. The interactions should direct the production processes towards a stable, planned state.
6. The interactions affect the whole schedule.
7. Following the interactions new situations arise.

In Behaviour-Based Control the possible and allowed interactions play important role. The interactions can be done at different hierarchical levels. The corrections should be initiated in up-down direction. A higher level correction may override the decisions of the lower hierarchical levels, lower level decisions can be even banned. The hierarchical BBC propagates new constraints form the upper level to down. The identifications of anomalies spread in bottom-up direction.

A POSSIBLE CLASSIFICATION OF BEHAVIOURS

Experiments show that a few numbers of classes are favoured in practical applications. For production processes the following general global states are suggested:
1.Normal, 2. Deviated, 3. Critical, 4. Dangerous. Normal state requires no interaction. In deviated situation the process does not go as planned: readiness for delivery is decreasing, jobs late, waste rate increasing, etc. The situation is critical if the original schedule becames unmaintable. Usually rescheduling is required. The situation is dangerous if the master production plan becomes unfeasible.

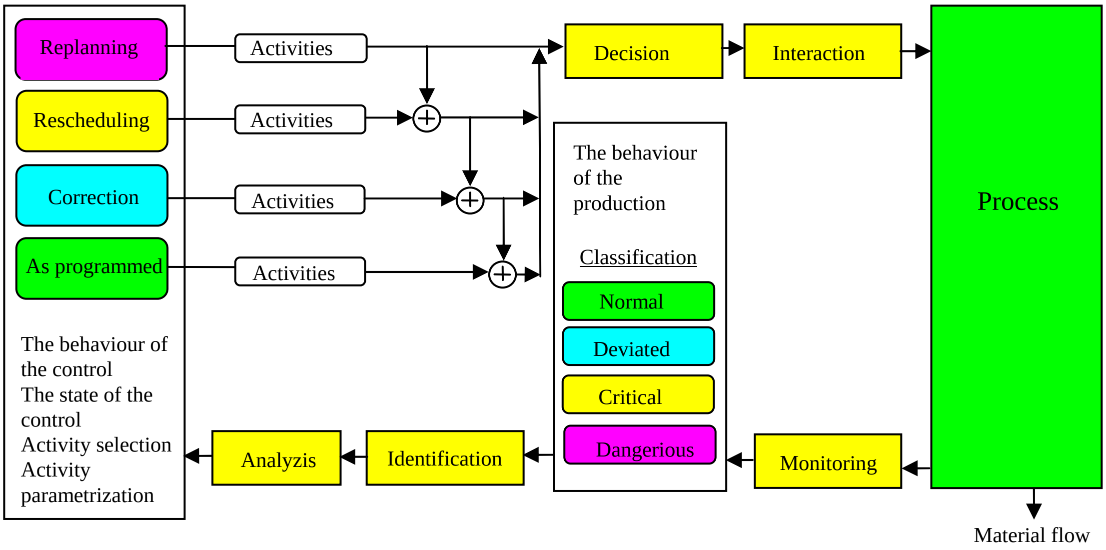

Fig 2. Behaviour based approach in production control

FUTURE WORKS

The behaviour-based production control and cockpit task management are new promising research areas. An Artificial Neural Networks based classification mechanism will be implemented as described previously. The feasible action for each situation will be investigated for a real manufacturing process (in the framework of VITAL project). The industrial and academic partners participating in the project, and the research work carried out so far are published in [17] and [18]. The results will be validated by a new fast production process simulator developed at the Department of Information Engineering of University of Miskolc.

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