UNCERTAINTY MANAGEMENT IN MANUFACTURING EXECUTION SYSTEMS

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ABSTRACT

During the last ten years the traditional Computer Integrated Manufacturing (CIM) concept has changed and got new content. The term: "Information Technology for Manufacturing" (ITM) or "Production Information Engineering" (PIE) means a lot of software applications that have been made to support all the production engineering activities. Today's modern IT for Manufacturing consist of hierarchical applications which are: Enterprise Resources Planning (ERP), Computer Aided Engineering (CAE), Manufacturing Execution System (MES) and Manufacturing Automation Systems. Production activities are performed in an uncertain environment. There are external and internal disturbances in the normal (or planned) production processes. Companies have to react to those disturbances to remain competitive in the market. Traditionally, uncertainty managing decisions were made only by skilled employees (e.g. master-workers, operators, shop managers, etc.). In modern, highly automated factories however computer applications can be used to collect production data, to detect unexpected events and to initiate corrective actions. This paper deals with the uncertainty management with special regards to Behaviour Based Control (BBC) and Cockpit Task Management (CTM). A proposal is also made how to insert uncertainty management into the scope of MES.

KEYWORDS: Manufacturing Execution System, Uncertainty Management, Behaviour Based Control, Cockpit Task Management

1. INTRODUCTION

Modern production information engineering systems highly utilize computer aided application systems. As a result of twenty years of research and development activities, four large application systems have been established which offer "turnkey" solutions for the engineers and the management to support decision making. They are as follows:

- Enterprise Resources Planning (ERP),
- Computer Aided Engineering (CAE), which includes Computer Aided Design, Process Planning, Production Planning and Scheduling (CAD/CAPP/PPS),
- Manufacturing Execution Systems (MES), and
- Manufacturing Automation (ME).

Figure 1 shows the usual hierarchical structure of integrated production information system. As can be seen, modern manufacturing uses numerous software applications for supporting the indicated system component.

The efficiency of the production is the key factor to remain competitive in the market.

2. NEW CHALLENGES IN COMPETITIVE ENVIRONMENT

The most important challenge for enterprises, whose value added based on automated assets is to develop the ability to use these researches to increase profit for the enterprise. This requires the use of a suitable management, engineering and execution system. The main tasks of this system are increasing the product quality, having high level utilization rate of the resources and being ready to good delivery capability.

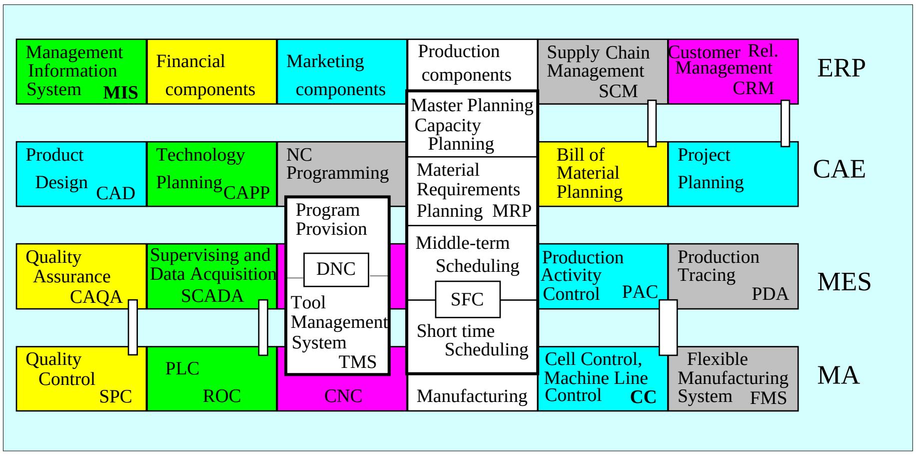

Figure 1.
Hierarchy of production information system components

High level production execution requires systematic tracing the production processes, triggering the disturbances and to make reactive actions, with monitoring the production activities and quickly recognize and overcome growth lateness, idle machines, high buffer levels or waste. The efficiency of the operational processes must continually be increased, and their risks minimized. The latter also applies to strategic (long-term) risks, such as the risk of following the wrong market trends.

The key to this is the availability of the corresponding objective information on the process, the status of the orders, jobs, or pallets and resources status. The existence of data acquisition methods and practice that enable a fast and efficient information exchange between the operators, shop floor managers and the production planners in the enterprise is very important. The goal is to ensure that the information is put to its best use, which is enabled by the implementation of suitable MES application. Both Production Planning and Scheduling (PPS) and MES with Monitoring and Process Management (MPM) systems provide the basis for flexible and effective production. These applications improve decisions on production processes, and also on the engineering activities and resource utilization. This should enable the enterprise to continually control and optimize its short and long-term activities in a dynamically changing environment.

3. OVERVIEW OF DISTURBANCES IN PRODUCTION

During the production activities numerous disturbances may happen. They can be external or internal ones. When modelling the disturbances and uncertainties of production activities a hierarchical model can be set up. It may include the following levels in *bottom-up* direction:

1. Problem in quality assurance – indicated by the increased waste goods rate.
2. Resources utilization issues – indicated by the difference in planned and achieved production descriptor indices.
3. Out of stock error in production – indicated by product tracking data.
4. Supply chain issues and co-ordination problems at the shop-floor- indicated by missing due date.
5. Daily scheduling issues – indicated by continuous need for rescheduling.
6. Production planning issues leading locked batches, very complex or unresolved scheduling plans.
7. Prognosis (forecast) problem indicated by the growth of inventory or Work in Progress (WIP) level.
8. Problems in order management in production planning leading to reduced delivery capability or reduced satisfying level of consumer needs.
9. Problems in production/packaging specification, merchandizing, and reliability.
10. Problems in IT services - indicated by low readiness of IT services.
11. Problems in investment and marketing.
12. Management, organization, scope of authority problems.

It is very difficult to model how the individual disturbances affect the production and business processes. Each kind of problem may require its own corrective action at the appropriate hierarchical level. Furthermore disturbances may happen concurrently thus affecting to each other. Consequently handling uncertainties in the real word is a very complex task.

Many unexpected event happen at shop floor level. MES should be based on a good manufacturing model.

The operations model, which consists of production orders, jobs, resources, production processes, monitoring and control systems, events and performance indices, is embedded into the engineering database. For achieving good production performance companies have to invest MES modules and integrated collaborative supply chain management processes that integrates all execution activities on operation level, so that customers can be served at high level, with better quality and at lower costs.

Uncertainty plays a big role in the customized mass production industry, too. There is a lot of uncertainty in the market for product types, seasonal prices, need for special packages and in the limited delivery date. In order to handle these uncertainties better and to make more robust decisions different management models are generated. These models are in general large-scale, nonlinear and contain uncertainty in the parameters too. The most important way to reduce the uncertainty is to use the feedback control in the production activity control level. Behaviour Based Control (BBC) is a general control technique used first time in the robot control area and lately also in other production engineering fields.

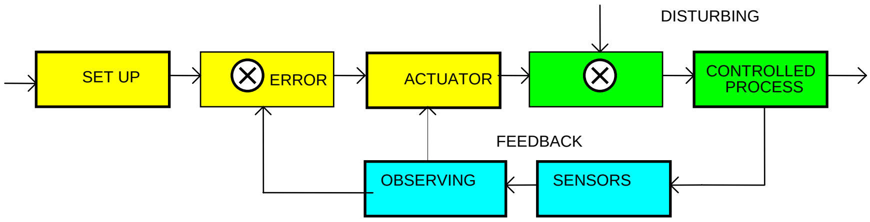

Figure 2.
Feedback control loop for eliminate disturbances in controlled process

Like the Kalman Filter for state controlled linear systems, the observer module of BBC determines state variables and weighted average of performance measurements. These statistics make it possible to compare planned and real pointers.

4. BEHAVIOUR BASED CONTROL IN MES

Real-time control of Manufacturing Execution Systems has the following computer aided tools:

1. observing and data acquisition,
2. monitoring, tracing, supervising,
3. Behaviour Based Control (BBC),
4. analysis, evaluation by Human Machine Interface (HMI) – also known as Cockpit Task Management (CTM),
5. diagnostics and
6. prognostic tools.

It is expedient to have a *bottom-up* approach having incremental expenditure of functionalities when developing a system dealing with uncertainties. Behaviour based control proved to be successful in robot control [2].

Behaviour-based controllers consist of a collection of behaviours. Behaviours are processes or control laws that achieve and/or maintain goals. For example, 'avoid-obstacles' maintains the goal of preventing collisions; 'go-home' achieves the goal of reaching some home destination. Behaviours can be implemented either in software or hardware; as a processing element or a procedure. Each behaviour can take inputs from the robot's sensors (e.g., camera, ultrasound, infrared, tactile) and/or from other behaviours in the system, and send outputs to the robot's effectors (e.g.: wheels, grippers, arm, speech) and/or to other behaviours. Thus, a behaviour-based controller is a structured network of such interacting behaviours. Note that behaviours themselves can have state, and can form representations when networked together. Unlike reactive systems, behaviour-based systems are not limited in their expressive and learning capabilities [3].

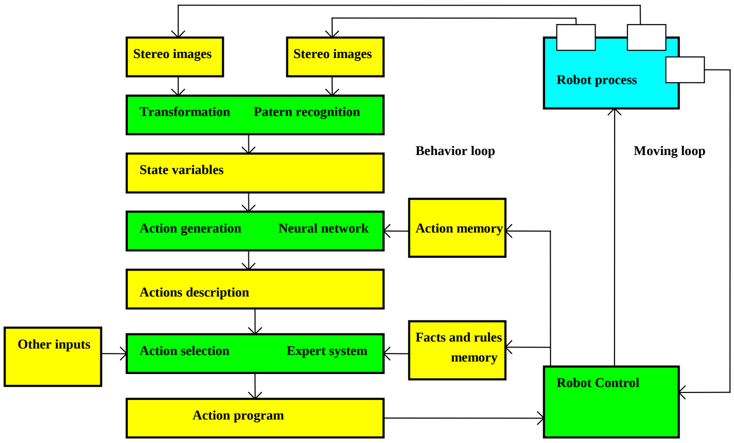

Figure 3.
BBC in robot control

The following fundamental principles should be emphasized:

1. Modelling of mass production requires complex model having a large number of parameters.
2. The change in the state of the system can be respected as behaviour. Perspicuity can be increased when behaviours are categorized into discrete categories.
3. Making corrective actions should focus on the level and mode of interactions. Individual behaviour categories can be assigned to interaction categories.

BBC is feasible for making automatic corrective actions. Most of the cases however require human experts to make decision and/or interaction. This requires interactivity thus Human Machine Interface plays an important role besides data aggregation, analysis, computing of management indices and cockpit techniques.
The term Cockpit Task Management originates from error handling in flight control. CTM involves recognizing and coordinating flight crew goals; prioritizing the goals based on importance, urgency, and other factors; and performing tasks to achieve those coordinated and prioritized goals. In order priority required actions are as follows:

- Aviator: controlling the airplane.
- Navigate: determining where the airplane is, where to go, and how to get there.
- Communicate: communicating with air traffic control.
- Manage systems: configuring and correcting power plant, fuel, electrical, hydraulic, and life support systems.

CTM performance is satisfactory when there are no conflicts among the goals, the goals are properly prioritized, and at least the highest priority tasks are being performed satisfactorily [4].

Customized mass production requires HMI – a cockpit – which becomes the main tool to make real-time interactions.

5. UNCERTAINITY MANAGEMENT IN MANUFACTURING

Figure 2 depicts a generic control loop of controlled processes. If manufacturing were work without any disturbing then no interaction would be necessary. Unfortunately, processes of real life coupled with disturbing. Table 1 compares the most widely used control methods.

Table 1
Comparison of control methods

	Proactive	Reactive	Adaptive	Learning
Model	**known**	**stochastic**	**incomplete**	**unknown**
Goal of control	**defined**	**changing**	**defined**	**changing**

Production Information Research Team of Department of Information Engineering of University of Miskolc participates in an industrial project called ‘*VITAL*’, where the main goal is to support uncertainty management by modern IT tools. An important topic of the project is to deal with real-time production control with changes and disturbances.

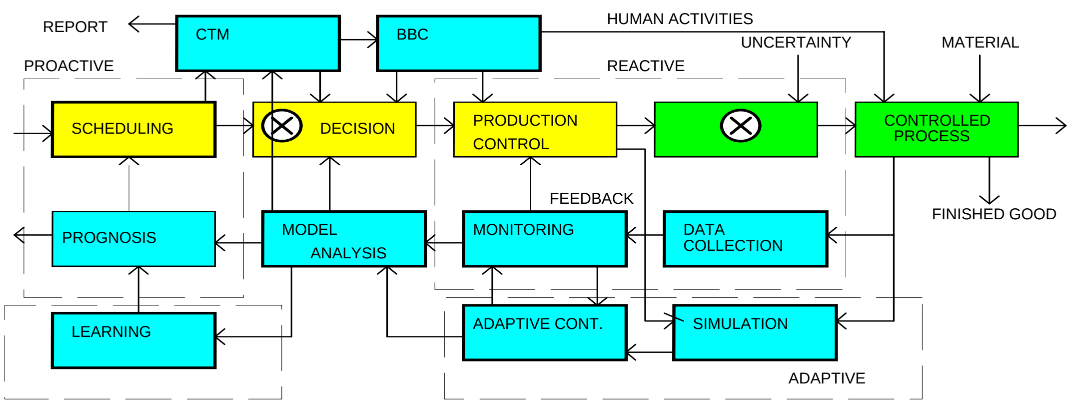

Figure 4.
BBC control conception for production processes

To solve the problems of uncertainty management on production is a complicated task. In Fig. 4 we show a general conception for the control architecture of BBC for manufacturing applications. For BBC and CTM module Data acquisition, Monitoring and analysis are the main information searches. Model based simulation and adaptive control algorithm are also applicable. Prognosis and Learning module should use machine intelligence methods.

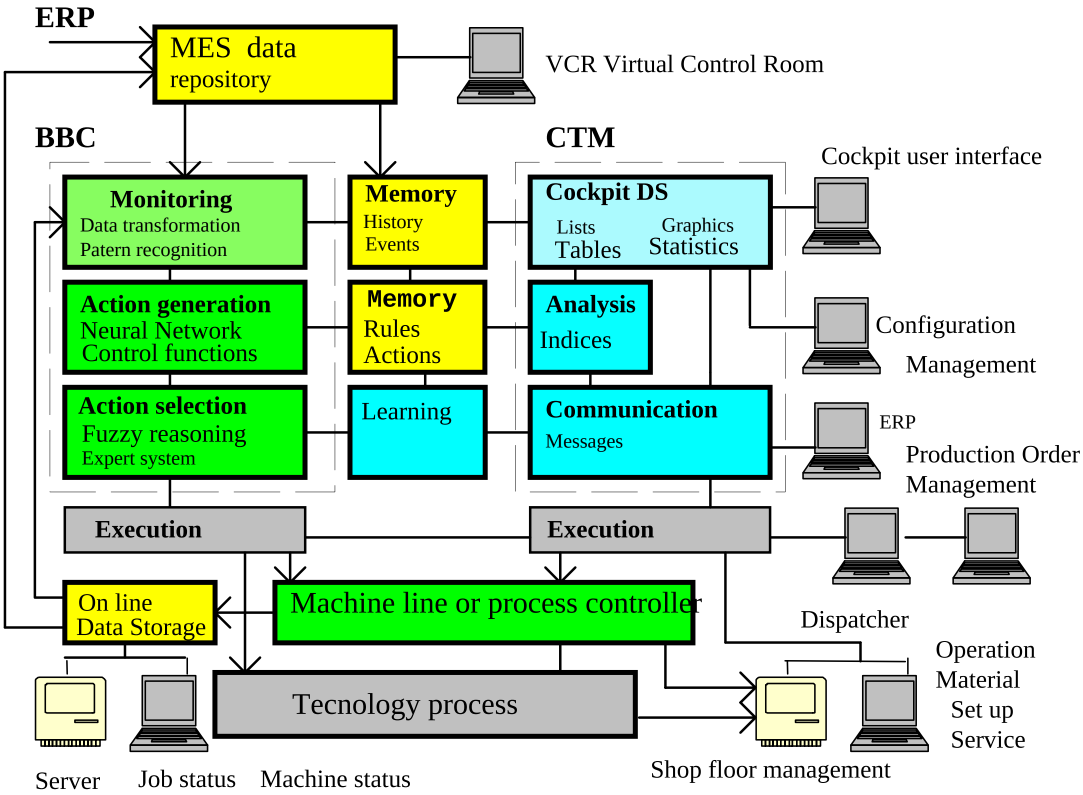

Figure 5.
Component of BBC and CTM control of auto mated assembly line

In customized mass production automated assembly lines are the typical main machine resources. The complex control of this machine consists of a number of Programmable Logic Controllers, industrial network and supervisor industrial computer. The BBC and CTM extensions may use the on line data storage of machine line control and the MES data repository. It contains the data of planned and finished orders, jobs and pallets. BBC recognises deviant, critical or dangerous difference between planned and real data. CTM shows production performance indices and suppose corrective action or send messages for planners on higher level.

CONCLUSIONS

1. One of the most important areas of applied information engineering is the Production Information Engineering.
2. Integrated application systems play more and more important role on the field of Production Information Engineering.
3. In the most practical cases there is no possibility to use only one analytical model even on the same level of different firms because of complexity of the production process.
4. Applying state variables (demand rate, production rate, utilization rate, stock level, average lead time, number of setups, and number of jobs to be lateness) are very effective tools for optimization production processes.

5. Uncertainties make difficult to plan production processes even middle time horizon. The main tools for managing uncertainties are the fast, real time decision support systems such as BBC and CTM modules.

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