Agent technology used for monitoring of automotive production

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Abstract

Today's automotive plants are equipped with heterogeneous software systems for different types of tasks, both factory planning and manufacturing operations. IT systems used for factory planning are summarized as 'digital factory tools'. On the operating level, software systems are not yet integrated and thus support separate tasks such as production order control, production monitoring, sequence planning, vehicle identification, quality management, maintenance management, material control and others.

A very promising technology for integrating existing software systems and their functionalities and to add assistant systems for the shop floor staff is to be found in software agents. In this paper the author describes the current use of software agents for today's production tasks and his vision for applying agent technology in future automotive production.

Keywords

Production monitoring, production control, automotive production, order management, software agents, digital factory

1 Current situation analysis

1.1 Software support in automotive plants

Owing to the fact that the work load taken on by OEMs and suppliers has shifted to the benefit of the suppliers, OEMs have to focus increasingly on monitoring the production processes, on logistics and supply chain management, including the shop floor level. Today, shop floor staff use production monitoring tools that support manufacturing decisions which are merely based on production quantities. In the case of a facility breakdown or quality inspection results they only know that a certain number of vehicles is affected. However, they can neither identify the customer orders related to these vehicles nor their options, e.g. color, right or left hand drive, sun roof, etc. It would be a big step forward towards better and more transparent decisions if the shop floor people could base their decisions on identified vehicles/customer orders rather than on undefined production quantities. Production monitoring systems play a relevant role in supporting manufacturing operations; and, what is more, they can be seen as the operational part of the digital factory [Sauer, 2004a] (see Figure 1).

This means that in the years to come the above-mentioned production monitoring, maintenance management and logistics control systems will have to be integrated (see Figure 2) so as to allow for better and more transparent decisions and to recognize the impacts of decisions taken on the shop floor on just-in-sequence parts to be provided to the line, for instance. Another driving force behind new software technologies is the increasing number of vehicle models having ever shorter life cycles. IT systems must be more flexible with regard to changes and adaptations to the new model requirements.

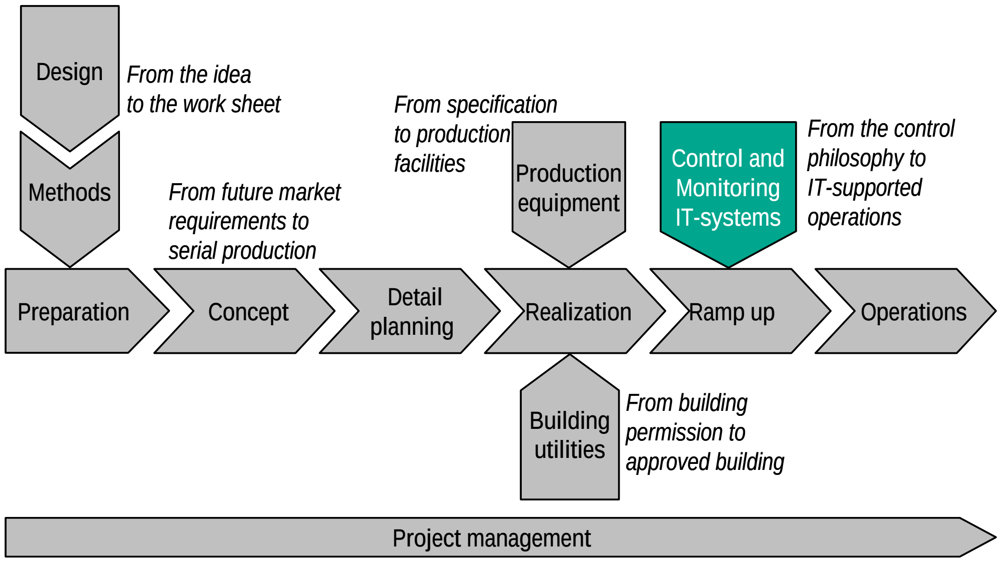

Figure 1: How production monitoring and control systems fit into the processes of a car factory

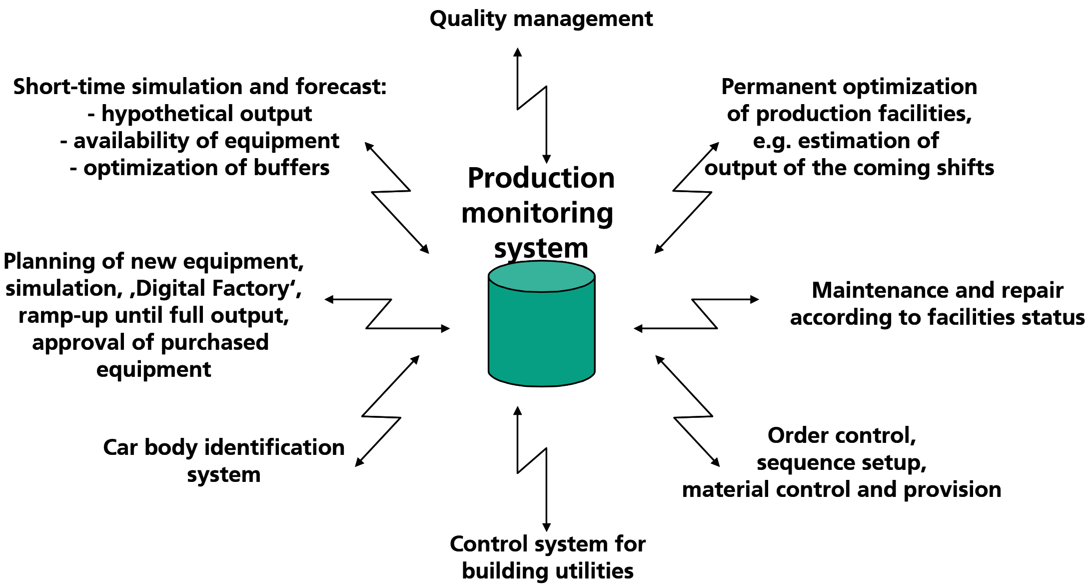

Figure 2: Examples of IT systems in today's automotive plants

Currently, a new generation of shop-floor related software systems is being developed - 'manufacturing execution systems' - to bridge the gap between today's stand-alone IT solutions. It is, however, evident that the software technologies applied today are not powerful enough to integrate existing software systems and deliver the required results, namely support of manufacturing decisions on the shop-floor level regarding all relevant aspects of production equipment, quality issues, provided parts and shift output. The integration aspect is in most cases supported by databases (Figure 3). It must be added that a couple of the above-mentioned systems, particularly those for production monitoring, require real-time data processing instead of database solutions because they receive a large number of signals from the programmable logistics controllers (PLCs) of the production equipment. For real-time applications, database solutions are often not fast enough.

Another disadvantage of integration by means of a database is the required data model for all related applications. This data model is comparatively inflexible, particularly if changes or extension of functionalities are required or if new IT systems must be added. Additionally there is no software supplier (compared to commercial IT applications) who would be able to deliver all required modules for an automotive plant as a single-source supplier.

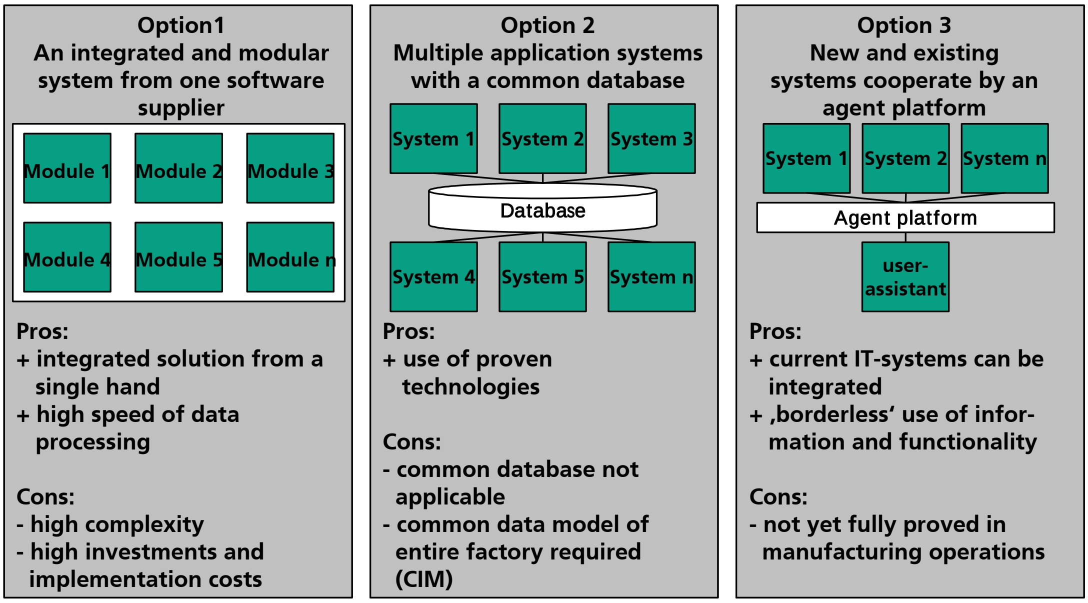

Figure 3: Possibilities for OEMs to integrate different software systems

In the late 1990s a team of the Fraunhofer IPK developed a first concept for an Asian OEM allowing to integrate some of the above-mentioned IT systems, particularly those on the cell manufacturing level (see Figure 4). Being ahead of their time, the Fraunhofer people designed a cell manufacturing system that combined production monitoring, quality control, maintenance / repair and tracking information for each shop - press, body, paint and trim shop. Applying the available software technology of that time, the plant in question went into operation in 1998.

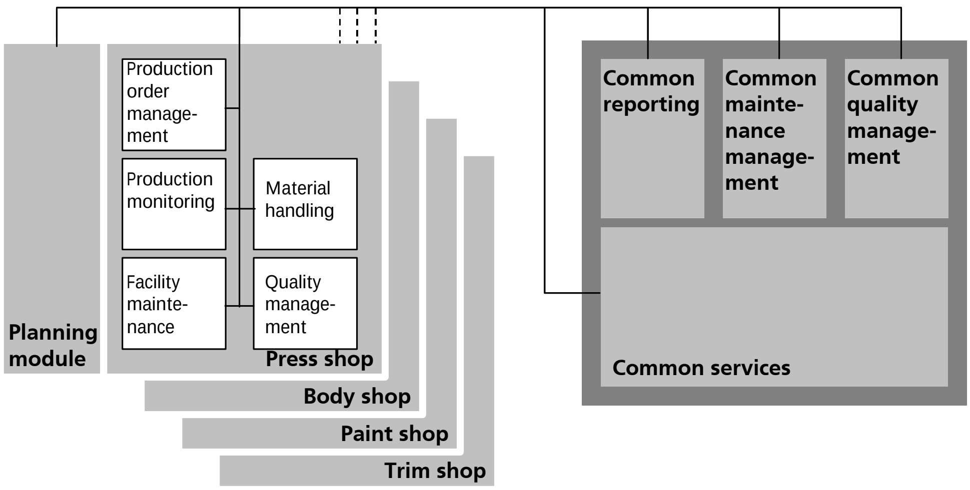

Figure 4: Overview of the cell manufacturing concept developed by Fraunhofer IPK [Albrecht et.al, 1996]

Today it is evident that new software technologies have to be used to allow for a genuine integration of IT systems for production equipment, quality issues, provided parts and shift output and to preserve the existing software functionalities.

Let's assume it is useful to bring some of the existing operational IT systems of an automotive plant together - the user would be lost in view of the variety and abundance of functionalities. This means that a user-oriented assistant software that makes available the required functions and information for a specific working activity is essential for the users on the shop floor to take the required and expected decisions.

1.2 Agent technology in practical use

A more promising technology for integrating existing software systems and their functionalities and to add assistant systems for the shop floor staff is to be found in software agents. In the academic field, agent technologies have a long tradition, but their use in production and real-time applications has been very limited yet. Describing the state-of-the-art for agent-based systems we concentrate in the following on practical applications especially in automation applications. One of the first promising applications is described by authors from DaimlerChrysler [Bussmann, 2000; Sundermeyer, 2001] who have implemented a manufacturing cell for cylinder heads and other engine parts that is completely controlled by a software-agent-based system. The manufacturing cell works in serial production and has produced excellent results concerning capacity utilization and smoothed production. The control logic developed in this project by the PLC-supplier [Colombo, 2001] is offered for further industrial applications. Most authors refer to this example to prove agent-technology being applicable on the shop floor.

Hertzberg et.al describe results of the AgenTec project which have been applied to a prototype of a commissioning system to illustrate and test the integration of heterogeneous software and control systems [Hertzberg, 2003]. Further examples for potential application in automation technologies are summarized by Urbano et.al. [Urbano, 2003]. However, an industrial application is still missing.

2 Research and application development visions

2.1 Closed control loops and connection of monitoring and order management

The main ideas behind the closed loops as shown in Figure 5 are the following: there is in fact a connection between the concept of a factory and its control and monitoring during actual operation. The control philosophy, e.g. PUSH or PULL, has essential impacts on a factory's design and therefore on its profitability and flexibility. As a consequence the demands for future IT support of the enterprise are determined in a factory's initial conceptual phase. The tools of the 'digital factory' must in future integrate these linkages [Sauer, 2004b].

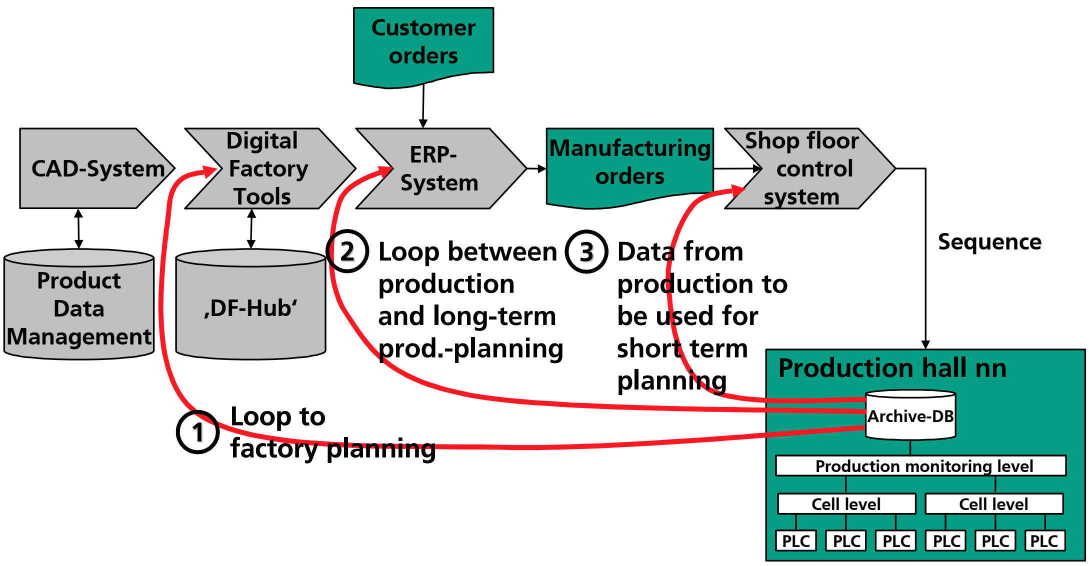

Figure 5: Establishing closed loops between production monitoring and control

In detail the following three issues have to be tackled:

1. The purpose of the 'digital factory', to begin with, is to minimize the investment risks with regard to the equipment (machines and installations) during the entire planning process of a factory. This results in new demands for planning tools, which must cope with imprecise and uncertain input data. The 'digital factory' can be compared to a factory-DMU (digital mock-up) with the difference that relevant simulators additionally allow predictions as to the dynamic behavior of the factory. Ideally, the input data used in the simulation are actual plant data recorded and processed by the production monitoring

and control system. This feedback will lead to more reliable results of a planning process, because planning people can access real production data instead of estimated values.

2. Secondly, the information that is held in an archive database of a production monitoring tool might support the weekly or monthly production planning. The benefits are evident: not only will this result in more precise production plans, e.g. used as forecasts for suppliers, but also in better maintenance plans based on real and permanently updated statistical data of the production systems behaviour ('maintenance-on-demand').
3. The most interesting and most difficult point is to use production monitoring information for short term planning, e.g. daily sequence planning. To close this loop means to release manufacturing orders taking into account the actual status of the running production, e.g. actual and unexpected downtimes of production equipment. Such a closed loop would also lead to the fact that OEM's could shorten their 'frozen zone' period. As a prerequisite the production monitoring system is combined with the car body identifying system, e.g. RFID-readers of 2D-bar code-readers.

2.2 Virtual Startup

When talking about manufacturing the buzzword 'digital factory' appears everywhere these days. DaimlerChrysler announced that they would in future not start any new work sites or production plants without first carrying out digital testing. An expert committee of the VDI (Society of German Engineers), in which the IITB is represented, recently defined the term as follows: "'Digital Factory' is a generic term for a comprehensive network of digital models and networks, which includes, among others, simulation and 3-D visualization. The purpose of the 'digital factory' is the overall planning, implementation, control, and continuous improvement of all factory processes and resources in connection with the product" [Bracht, 2004]. In the future the 'Digital factory' will not only be used for factory planning. It is the vision to use the information stored in Digital factory databases to automatically configure and customize the production monitoring and control system's engineering part. It is already possible to automatically generate PLC programs from the virtual testing and commissioning (Figure 6).

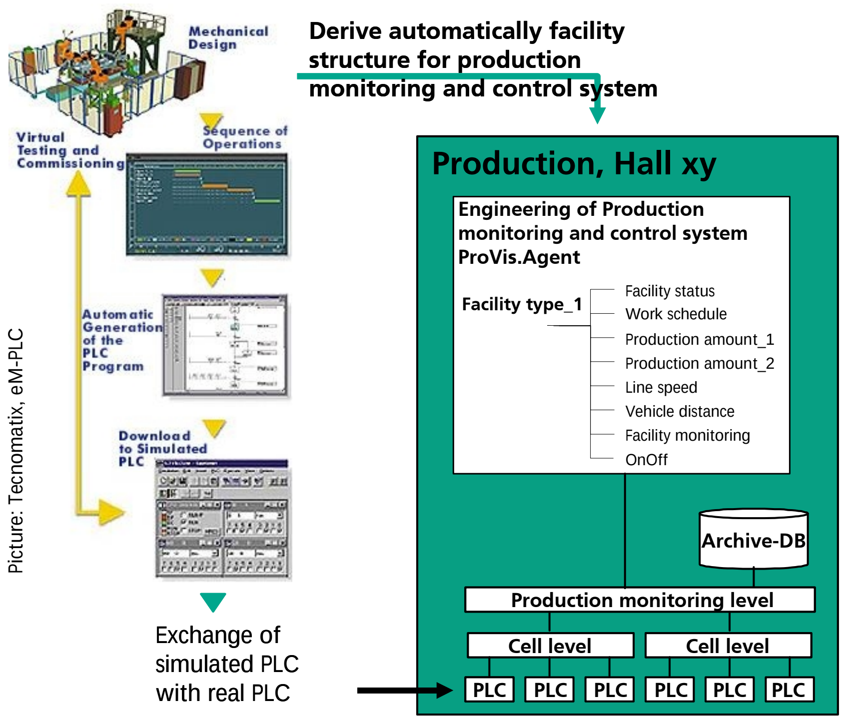

Figure 6: Virtual startup

2.3 Intelligent car bodies in a modular structure of production

In a recently conducted project an OEM developed the concept of a new, modular structure to manufacturing his cars. Instead of pushing the car bodies over a coupled production line with more or less fixed cycle times, the production is split into modules that are decoupled and provided with car bodies by a car body logistic centre. This new production philosophy means completely new ways of production management, shop floor control and manufacturing monitoring.

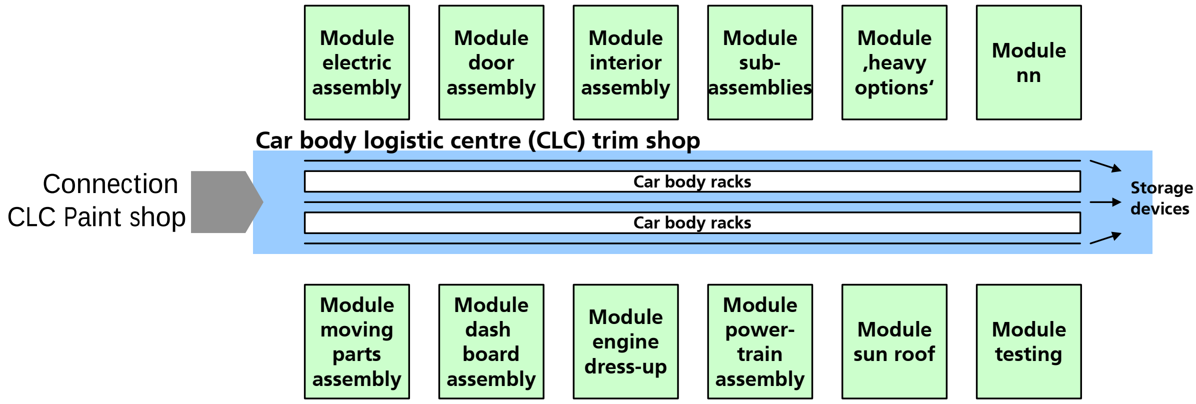

Figure 7: Modular structure for the trim shop (example); source: SimPlan AG, Maintal

3 Production monitoring system based on agent technology

In the field of production monitoring, maintenance management and cooperation with logistic-oriented IT systems, there still remains much room for manoeuvre for the application of software agent technology. To make it clear: today there doesn't exist any application of software agents in production monitoring and its real-time data processing - neither in the automotive industry nor in other branches. The model described in the following is therefore not just another agent based model but something completely different compared to today's production monitoring systems.

The development team at the Fraunhofer Institute for Information and Data Processing (Fraunhofer IITB) developed an agent-based production monitoring system and connected it to an assistant system which simulates the output of an automotive shop for the next three shifts on a short-term basis [Sutschet, 2001]. With the help of this assistant the shop floor personnel is able to foresee the impact of any kind of disturbance caused by unexpected changes in the production equipment, the buffers and the material flow systems, e.g. conveyors, skids, etc. This supports the manufacturing people in their short-term decisions concerning shift capacities, increase or reduction in staff in the coming shifts, assignment of workers to the line, etc.

The agent-based production monitoring system is a new version of the Institute's existing system [Früchtenicht, 2000] in DaimlerChrysler's Bremen plant where it monitors and controls the shops for body, paint and assembly either from a central control room (see Figure 8) or from decentralized control panels on the shop floor. The functionalities of the agent based system are almost the same as in the current software system called 'ProVis', but the modules of various systems have been wrapped and enabled to communicate via a standard agent platform (JADE). Examples for these modules are

- the different input/output channels for the process data submitted from the PLCs,
- process variables such as production amount, status of line buffers, switches, etc., that are computed in the monitoring server,
- the interfaces between the monitoring server and its clients,
- archive functions that are conducted in a separate archive server and

- information clients with interfaces either to the above-mentioned assistant system or other services, e.g. radio/alarm server.

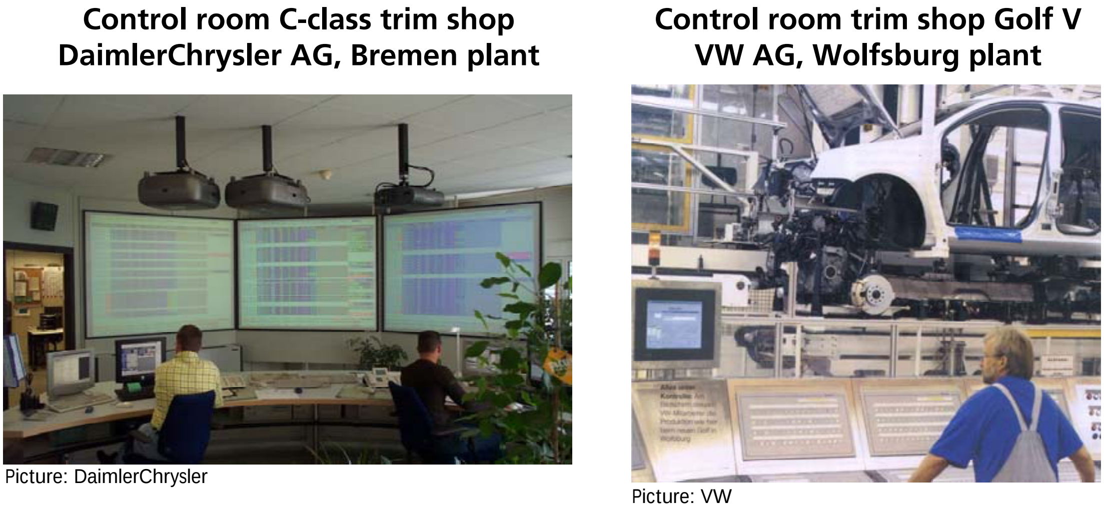

Figure 8: Central monitoring and control rooms

An example of the layout of such a new production monitoring and control system which is now open to be connected to IT systems related to logistics, quality management or building utilities control is shown in Figure 9.

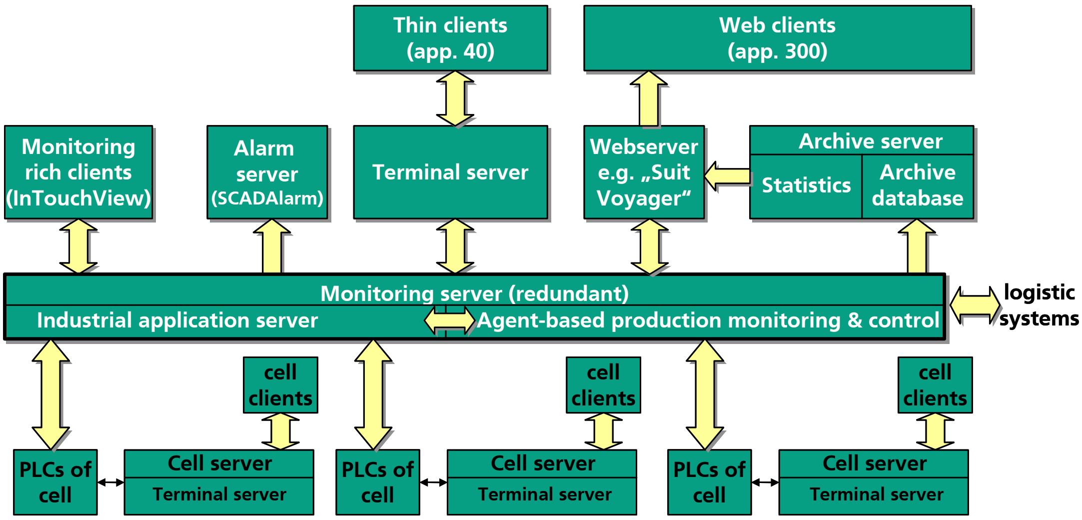

Figure 9: Example of an agent-based production monitoring and control system using some commercial applications, e.g. for visualization (SCADA)

This architecture allows to cooperate and communicate with other existing IT systems and, what is more, enables their functions to be used by the agents of the production monitoring system. Agent-based monitoring and control systems in automotive plants will allow to adopt ‘plug and produce’ procedures for more and more intelligent production systems in the coming years.

As one example of the above-mentioned assistant systems the IITB implemented a software solution that calculates for the 3 – 5 coming shifts the production output regarding all actual production breakdowns indicated by the production monitoring system as well as the buffer status calculated according to the current production output (Figure 10). In this case the interface shown in Figure 10 is WinCC. With the help of this assistant software, which is connected to the monitoring systems by a software agent, the shop floor people can react to failures on the shop floor level quickly and correctly. They are now able to adjust line speed and the work force for the coming shifts and to take efficient measures to keep the output as high as possible.

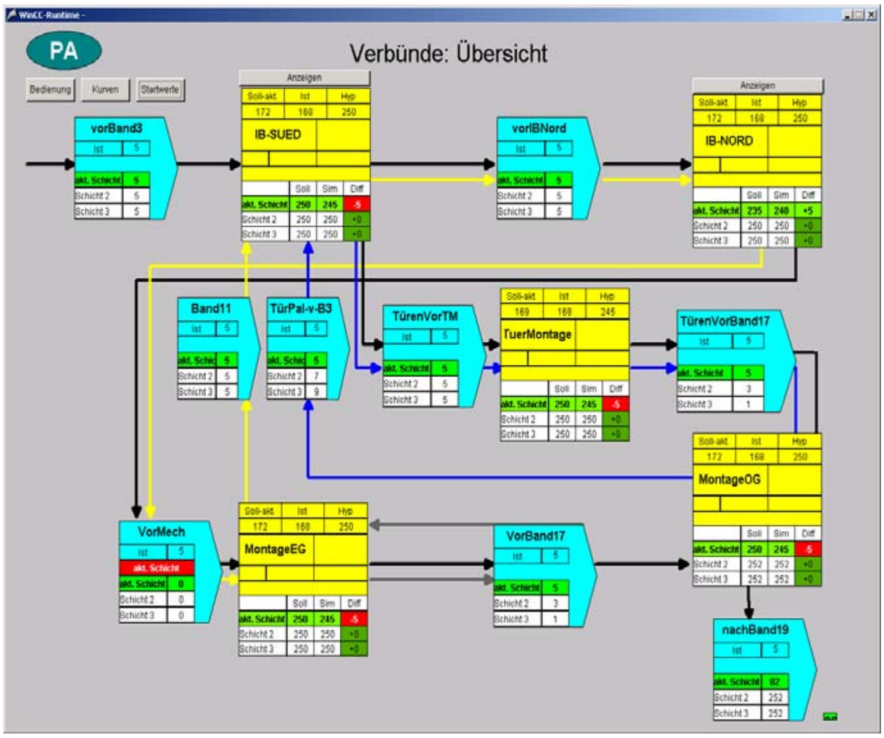

Figure 10: Short-time simulation system as production assistant tool connected to the production monitoring system

References

Albrecht, R.; Mertins, K.; Sauer, O.: Keine Bindung an den Kundenauftrag. Automobil-Produktion, August 1996, S. 86-88.

Bracht, U.: Die Digitale Fabrik in der Automobil-Industrie – Vision und Realität. Proceedings der 5. Deutschen Fachkonferenz Fabrikplanung, 31.03.-01.04.2004. Landsberg: Verlag Moderne Industrie, 2004.

Bussmann, S.; Schild, K.: Self-organizing manufacturing control: an industrial application of agent technology. Proceedings of the 4th International Conference on Multi-Agent Systems, 2000.

Armando W. Colombo, A.W.; Neubert, R.; Schoop, R.: A Solution to Holonic Control Systems. Proceedings of the 8th IEEE International Conference on Emerging Technologies and Factory Automation, ETFA Oct. 18, 2001.

Früchtenicht, H.W.; Sassenhof, A.: Werksweites Produktionswarten- und Anlageninformationssystem. In: annual report, Fraunhofer IITB, Karlsruhe : IITB, 2000, pp. 62-63.

Hertzberg, J. et al.: Agententechnologie zur Integration heterogener Systeme am Beispiel eines Prototypen für ein Kommissioniersystem. Proceedings zur SPS/IPC/DRIVES 2003, 25.-27. November 2003.

Sauer, O.: Einfluss der Digitalen Fabrik auf die Fabrikplanung, wt werkstattstechnik online 01/2004, pp. 31-34.

Sauer, O.: Digital Factory – A comprehensive network of digital models and methods, visIT International 2004, pp. 12-13.

Sundermeyer, K.; Bussmann, S.: Einführung der Agententechnologie in einem produzierenden Unternehmen – ein Erfahrungsbericht. Wirtschaftsinformatik, Vol. 43, No. 2, pp. 135-142, April 2001.

Sutschet, G.: Störung im Griff. Ein Produktionsassistent für die Automobilfertigung. visIT 2 (2001), No. 2, pp. 6-7.

Urbano, P.G.; Wagner, Th.; Göhrner, P.: Softwareagenten – Einführung und Überblick über eine alternative Art der Softwareentwicklung. Teil 2: Agentensysteme in der Automatisierungstechnik: Modellierung eines Anwendungsbeispiels. Automatisierungstechnische Praxis atp 45 (2003) Heft 11, pp. 57-65.