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Modeling, simulation, and control of production resource with a control theoretic approach

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Abstract

Regarding the changing market environment in terms of logic requirements, production planning and control recently contribute significantly to fulfilling these demands. Logistic command variables, particularly adherence to schedule, are becoming the crucial parameters to satisfy the customer's needs.

Cyber-Physical production Systems (CPPS) with their characteristics decentralized organization, autonomous control, real-time capability and smart data processing offer new possibilities of production monitoring and control.

For this purpose, this paper proposes a new event-based approach in order to improve adherence to schedule in production by using the potential of CPPS. Control loops close to production shop floor provide a fast identification of events. Based on an activity list, the production control is able to react adequately to the different events e.g. machine disturbance or urgent orders. The activities initiated by the Manufacturing Execution System (MES) affect the whole production system while the production. In a final step, the developed concept of an event-driven production control was implement in a simulation.

Keywords: Production planning; Control; Digital manufacturing system

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1. Introduction and status quo

The research and application area of production planning and control (PPC) looks back on a varying history. Not only it adjusts to new industrial challenges, but also tries to be one step ahead [1]. Due to Industrie 4.0, also known as Internet of Things (IoT) or the like, the PPC is confronted with new challenges [2]. Already at the beginning of the 1980s, with growing computing capacities and the availability of graphical screens, a new era of production control began [3]. Closely followed, in the mid-1980s by Lean Production and mid-1990s by Supply Chain Management (SCM), the PPC revolutionized stroke upon stroke. Today, increasing computing capacities allow to solve more and more complex problems [4]. Thus, extensive requirements, like high rate of variant diversity, are encouraged. In order to meet the requirements and to eliminate uncertainties, simulation models are used [5]. Simulation models provide adequate analytical approaches to assess decision alternatives. Hence, simulation models play a significant role. They have to adopt to any condition of a production area and its varying requirements as fast as possible [6], [7]. In the course of Industrie 4.0, future production environments are supposed to be intelligently linked and machines should communicate in real-time [8], [9]. Therefore, simulation models have to be real-time capable. In the future, machines are consolidated to CPS, CPSS and CPPS [10].

According to Nyhuis [11], Industrie 4.0 holds a lot of potential regarding the degree of accuracy of production planning. To exhaust all potentials the PPC pursues new trends. In order to understand these trends, the current situation within the production environment and industry has to illuminate. Due to increasing variety of products and changes in consumer behavior, producing companies are asked to improve their processes [12]. Even during peak load times producing companies have to be reliable and economical. Therefore, a

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maximum degree of flexibility is expected, especially with decreasing quantities and rising variety of products [13]. The coordination of machines, workers, material and other resources, implies increasing complexity and sets highest demands to computing systems. Besides ever-present trends like setup-time minimization and idle-time optimization, a transition takes place from a central to a decentral data processing. The majority of modern production facilities gathers and processes machine data centrally. Following, computing systems process the machine data and send it back to the machines to control these [14]. Central data processing and control of machines leads to temporal shifts and consequently to an increasing error potential, due to readjustment. Also, known as “Inaccuracy of planning procedure” or “late data feedback”. A decentral production is able to process data in real-time and minimizes error potential [15]. This means, every machine is able to control itself by processing its own data. Simultaneously, interconnected machines in a production facility have to communicate with one another by passing on relevant machine data. Again, it’s about smart interconnected production [16]. This paper pursues the trend of PPC, that monitors and controls production in real-time.

The aim of this paper is to develop a machine model for fast simulations of production systems. The machine model is supposed to represent a modular work system, which is modeled with control engineering methods. At this, it should be a real-time system. Following the completion of the machine model, it’s intended to use the machine model as a module. So, e.g. several machines should be connected parallel or in series and machine parks of every kind should be simulated. Finally, known methods from the PPC are used.

2. Principles of control concepts

2.1 *Production planning and control*

Today’s production systems are controlled in different ways. At the same time, control systems depend on type and goal of a production system. So, besides capacity control, which is discussed in this paper, there are many possibilities to control production. For instance, order-generation and order-release control [17, 18, 19 and 20]. In this paper, the goal is a fast adjustment of an actual to a target performance, while the workload of the work system is kept steady. The target performance can also be seen as order performance. To ensure a realistic scheduling of production orders, it is necessary to control lead times in the production, in order to match the planning [18].

Hereto the two determining variables performance (eq. 2.1) and stock (eq. 2.2) are construed as control variables.

$$\mathrm{MP} = \frac{Output}{AR} \qquad 2.1$$

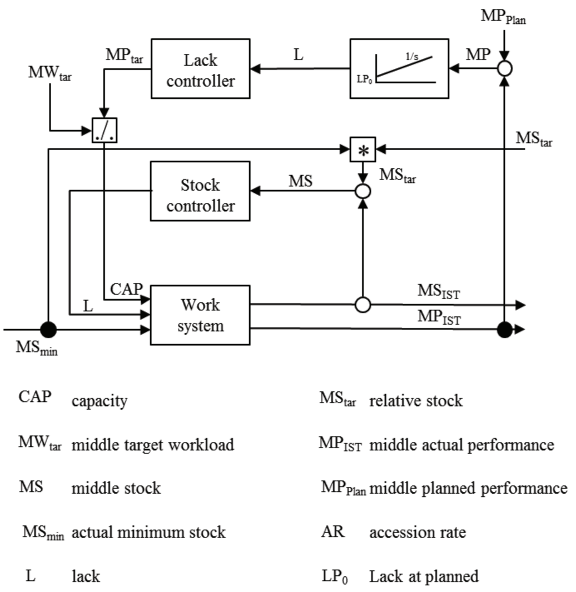

Fig. 1. Concept of a combined stock- and lag-control. [21]

$$\mathrm{ML} = \frac{MS}{AR} \qquad 2.2$$

$$\mathrm{ZDL} = \frac{MP}{ML} \qquad 2.3$$

As the funnel formula (ger. Trichterformel) [13] (eq. 2.3) shows, stock, performance and range are linked. Therefore, two of them can be controlled at the same time. Which these two are, was stated before. Furthermore, it becomes clear that not the middle performance (MP), but instead the overall throughput through the production system is of interest. As a result, a new variable comes into play and proves to be helpful. The so-called lack (L) is calculated as the difference between the middle actual performance ($\mathrm{MP_{act}}$) and the planned performance ($\mathrm{MP_{Plan}}$) integrated over time. Since capacity flexibility is assumed, lack can be controlled by capacity as manipulated variable. The lack controller calculates the capacity that has to be set and adjusts it at the work system [22]. In addition, the second control variable, stock (MS) is used and a so-called stock controller is applied. The concept of a combined lack and stock control is shown in figure 1. As the minimum stock ($\mathrm{MS_{min}}$), as manipulated variable, has low influence on the stock, the accession rate (AR) is used. The accession rate is calculated as the difference between actual and target stock. It has to be considered, that the accession rate is neither the target performance, nor the planned performance. When lack and stock controller are linked, they should not get in conflict with each other. In case of a lack, the lack controller reduces it by providing more capacity. Simultaneously the stock controller reduces the stock in the system in order to reduce the lead time. To avoid any conflict, a normalized operating characteristic is used. Nyhuis already recommends a universal use of production characteristics [22], since for most application areas they are mostly independent from system specific boundary conditions. If performance and stock are used