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Modeling approach for situational event-handling within production planning and control based on complex event processing

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Abstract

Nowadays industrial production environments are complex, volatile, and driven by uncertainties. Manufacturing companies are striving for flexibility and adaptability to cope with these challenges and remain competitive. Market requirements such as shortened product life cycles, increasing number of variants, and customized products lead to complexity in manufacturing systems. Possible approaches to cope with such challenges can be found in the field of 'Industrie 4.0'. In particular, decision-making and real-time reaction systems are one way to handle the complexity. To cope with this complexity, digitalization like the vision of 'Industrie 4.0' can offer different solutions. However, digitalization leads to an increase of the amount of data describing the status of products and resources within an industrial production environment. In order to achieve a near real time monitoring and control of production and logistics processes, intelligent processing and analyzing of the acquired data is necessary. As a result of this development, so called "complex event processing" (CEP) is essential for analyzing extensive data streams in real-time. In order to derive the rules for a CEP engine, an event model has to be described to visualize the relations, constraints and abstraction levels of production processes. The main focus within this paper is a modeling approach for the situational handling of events within production planning and control. The requirements of the modeling method are focused on the use case of a mass production for carbon-fiber-reinforced plastic CFRP components.

Keywords: Modeling; Production; Process control

1. Introduction

Multistage production processes with sequentially following process steps are characterized by complex relationships and interactions between the process parameters. Challenges for processing events in these production processes include the large amount and heterogeneity of the data, the high-speed requirement of these events, and the partially insufficient data quality. Therefore, there is a need to process the occurring events automatically, systematically, and promptly. For this to be achieved, the following objectives have to be fulfilled:

- Agility,
- responsiveness, and
- real time capability.

This corresponds to the idea of the Real-Time Enterprise (RTE), which stands for real time in the business world. All necessary information should be available at the right time [1].

RTE includes the electronic control of internal business processes as well as those that affect business partners and suppliers. The timely consideration comprises all projects, properties, and their current states interacting in real time.

A higher flexibility is achieved in process management using the RTE, whereby the company can respond more quickly. Other benefits include the cost savings, higher speed, and better product quality.

In order to achieve a near real time monitoring, control of production, and logistics processes, intelligent processing and analyzing of data is required. As a result of this development, Complex Event Processing (CEP) plays an important role for

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analyzing extensive data streams in near real time. CEP are methods, techniques, and tools to process events in real time [2]. For example, fraud prevention systems in the financial world are based on CEP. Fraud detection in banking and credit card processing also depends on analyzing events. This must be conducted in real time to prevent losses before they occur [3].

CEP is working on the basis of predefined rules and patterns, which have to be defined and expressed in an executable Event Pattern Language (EPL). The domain experts have the knowledge about the relations and dependences within the production processes. However, it is challenging for them to express these complex events in the form of event patterns and communicate with the technical CEP experts [4].

Therefore, one way to solve this problem is to use modeling methods in order to derive event patterns from the relations within the event model, and moreover to translate the knowledge into an EPL [5].

2. State of the Art

2.1. Event Model

According to Luckham & Schulte [6], an event can be defined as "everything that happens or is considered to be happening". For example, changes in sensor values or production failures can be considered as events. Furthermore, the incidents can be real or simulated as virtual events [6].

A further subdivision is the classification into physical and technical events or application and business events [7]. In comparison to physical and technical events, the application or business events are based on a higher level of abstraction and also have a higher expressiveness. They are generated by company applications, IT-internal incidents or human user input.

Physical and technical events are produced at high frequencies and in large quantities. The technical significance of these events - taken by themselves - is not of great importance. They must be related to each other and correlated with each other in order to increase their meaningfulness.

In the field of production planning and control, various types of technical events occur with different causes and triggers. Furthermore, unforeseen or expected events can be distinguished. The expected events occurring in a production scenario are, for example, logistical processes, confirmations at the beginning and end of work processes or the use of resources. Fraudulent and unforeseen events during the processing of orders, such as urgent orders, machine failures or missing equipment, usually affect the production processes in the form of interruptions and delays. These unexpected events are defined as disturbances in the literature [8].

The Electronic Product Code Information Services (EPCIS) is a standard for interface specification developed by Global Standards One (GS1). This enables a continuous process monitoring and efficient access to event data through a standardized, electronic directory [9]. In order to be able to depict different application cases, four event types are defined. The EPCIS event is the base class for all event types. Subclasses include the object, aggregation, transformation, and transaction events. An object event represents an event that is caused by a physical or digital object. When several objects are physically joined together, an aggregation event occurs. A transformation event occurs when one or more objects are processed to another object. On the other hand, a transaction event is an event in which multiple objects are linked to a business process. Each of these event types has four key dimensions that describe the object ("what?"), the date and time ("when?"), the location ("where?"), and the business context ("why?") [10].

The structured recording of the events in real time results in a higher transparency across the process chain. In order to be able to document production-relevant events of the individual processes, an extension of the EPCIS event is necessary [11]. Therefore the question "how?" is added. It represents the information about the process characteristics like sensor values. In addition to the four central questions, the data are enriched with detailed information regarding the processes. Thus, a higher transparency in the data acquisition level can be achieved. Such additional data include, for example, the detection of temperatures during transport, as well as process parameters which occur during production recorded by suitable sensors.

Various techniques are used in the literature to present structural event models. Some CEP systems do not use any modeling notation [12]. In addition, ontologies such as Web Ontology Language (OWL) and Resource Description Framework (RDF) play an important role. For example, Dunkel et al. [7] provide an OWL-based event model for describing a traffic management system. Rinne et al. [13] use a combination of RDF and OWL to develop their own event modeling language ODP. The class diagram of the UML provides another promising possibility for presenting event models [14].

EPCIS-Event

Data definition

Question	Information	Expression
what?	identification	EPC
where?	location	loaction = reading point alternative business step
when?	time	time stamp/date
why?	business context	process step

Extension

Question	Information	Expression
how?	process chracteristics	sensor value

Fig. 1 Extension of EPCIS event model (on the basis of [11])

2.2. Modeling for Event Processing

In addition to the event model, also the production processes have to be modeled. The relevant hierarchical and temporal relationships and limitations need to be described in a user friendly way on the one hand but also largely