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Procedia CIRP 57 (2016) 498 – 503

www.elsevier.com/locate/procedia

49th CIRP Conference on Manufacturing Systems (CIRP-CMS 2016)

A Data-Based Approach for Quality Regulation

Quoc Hao Ngo*, Robert H. Schmitt

Laboratory for Machine Tools and Production Engineering of RWTH Aachen University, Steinbachstr. 19, 52074 Aachen, Germany

* Corresponding author. Tel.: +49-241-8020695; fax: +49-241-22193. *E-mail address:* Q.Ngo@wzl.rwth-aachen.de

Abstract

In the customized production more complex processes are required. Companies are challenged by monitoring these complex processes which compared to mass production show a lower degree of standardization and are therefore characterized by higher instabilities. Quality management has developed various techniques to deal with instabilities such as error analysis and process monitoring, which are implemented successfully in mass production. These techniques are based on the principle of causality and are effective in identifying, monitoring and adjusting the main cause of error in isolated effect chains. Within the customized production the elimination of the main cause of error does not lead to a sustained improvement of production quality since causes of error differ due to varied products to be manufactured. Furthermore, processes in customized production increasingly imply immanent interdependencies. The emergence of quality along the value chain is thus getting more complex and can less be explained by an effect chain using the principle of causality. The data-based quality regulation is therefore developed in order to achieve high quality in complex production. This paper outlines the data-based quality regulation as well as its need for research. Afterwards, an approach based on a virtual production model to validate suitable data mining methods for the data-based quality regulation is provided.

Peer-review under responsibility of the scientific committee of the 49th CIRP Conference on Manufacturing Systems

Keywords: quality management, quality control, quality regulation, zero-defect manufacturing, quality 4.0, data-driven production

1. Motivation

During the time of mass production which was characterized by low product diversity and large quantities many quality methods for error analysis and process monitoring have arisen [1].

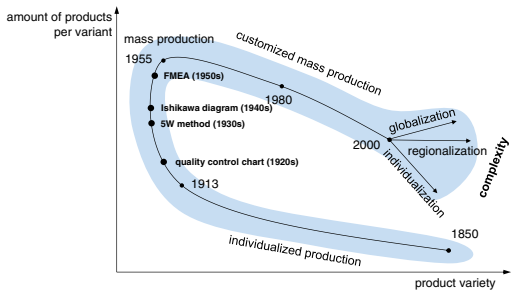

Fig. 1. Times of origin of quality management methods [2]

Although those methods asserted themselves in practice, especially in mass production, they hardly satisfy the requirements of customized production. The main causes of errors during the production processes can still be identified and remedied by using the trusted methods but it does not lead to a persistent improvement of quality. This originates in the different process operations claimed by every individual product. Therefore, the main causes of error differ, depending on the specific product to be manufactured.

Furthermore, different production processes in the customized production expose immanent interdependencies that arise between the individual processes and will continue to increase due to growing product complexity [3]. Owing to the interdependencies between processes the emergence of quality along the value chain is getting less transparent and can only partially be explained or traced by an effect chain. The following example illustrates the influence of interdependencies on product quality:

Peer-review under responsibility of the scientific committee of the 49th CIRP Conference on Manufacturing Systems
doi:10.1016/j.procir.2016.11.086

The process of laser cutting is made up of two parallel running sub-processes. On one hand the laser is guided while on the other hand robots simultaneously move the work piece that has to be cut relatively to the laser. By overlapping these two sub processes the final cutting shape results. However, a previous grind process can change the material property of the work piece as well as influence the result of the process of laser cutting. The interdependence between both sub processes and the grind process cannot be neglected considering the attainment of a high product quality. This example illustrates that due to increasing immanent interdependencies in production processes product quality can only partially be explained by the principle of causality. To explain the emergence of product quality the effect chain has to be extended to an effect network in which causalities of the effect chain remain while interdependencies between the production processes are added, and where the principle of correlation dominates.

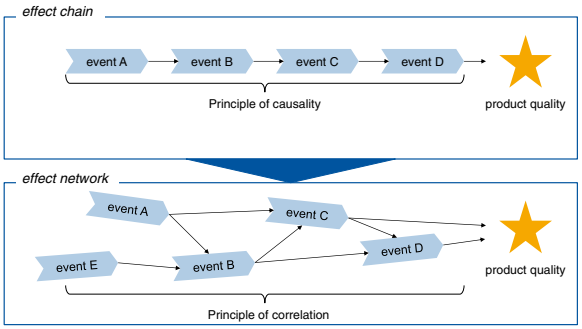

Fig. 2. Extension of the effect chain to effect network

The data-based quality regulation is an approach with the objective to enhance quality in production by controlling correlating production processes integratively. For this, the validation of suitable data mining methods regarding the intended objective is essential. Hence, the research question reads as follows: “How can data mining methods be validated taking account of the objective of data-based quality regulation?”

The state of the art puts emphasis on the potential and relevance of data for optimizing quality in production. The concept of the data-based quality regulation then is outlined with focus on further research needs. Finally, the approach to validate the required data mining methods is provided.

2. State of the art

Subsequently, the emergence of an increasing amount of data in industrial value chains and resulting potentials for quality management are explained. Moreover, existing tools for the processing and storage of huge amounts of data are presented.

2.1. Increasing amount of data along industrial value chains

The increasing amount of data in production provides new potentials for optimizing production quality. The goal-oriented analysis of all available data in production aims at a manufacturing at zero-defects and a learning factory that autonomously adapts to dynamically changing conditions [4]. Industry 4.0 as well as a systematic automatization and digitalization of production go hand in hand. This involves an expansion of sensor and communication networks, an interconnection of production plants through the implementation of cyber-physical systems as well as the assurance of disposability, transparency and security of data [5].

Huge amounts of data change the requirements for data storage. Recent approaches aim at storing and analyzing the data immediately during the process making use of auto-ID technologies such as RFID [6]. The storage of data at the product or specific components is striven. Like this each product or component knows how it has to be processed further. Different kinds of data can be stored directly at the product (figure 3).

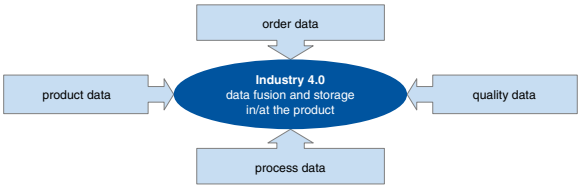

Fig. 3. Industry 4.0 aims at data storage in or at products

The storage at the product allows components or products to send crucial signals for process control for themselves [7]. This is not a negligible approach towards greater decentralization in production.

2.2. Increasing product quality through systematic data usage

Along with Industry 4.0 entirely new potentials especially for quality management arise which are discussed in science. Traditional methods such as the quality control chart which are past oriented can be expanded to a real-time quality monitoring [8]. In this context, we talk about a newly to design "Quality 4.0". The objective is the preventive avoidance of errors through the systematic and goal oriented usage of all available data. Quality data are necessary for specification as well as verification of product, process and system compliance. Quality relevant data represent an extension of quality data, as process, product or order data (see figure 3) can describe quality as well [9]. Figure 4 shows exemplary emergence points of quality relevant data along a production process.