June 21, 2011 (Tuesday) 55th EOQ Congress

CONCURRENT SESSIONS — **Tuesday 13:30 – 17:30**
KEMPINSKI HOTEL CORVINUS — **Erzsébet tér 7-8, Budapest V.**

REGINA BALLROOM II. — Tuesday 13:30 – 15:00

11.1. REPOSITIONING QUALITY FOR MANUFACTURING I. — 13:30 – 15:00

Session Chair: ***Hans Dieter Seghezzi***, *University St. Gallen, Switzerland*

14.10 Designing Closed Quality Control Loops for Stable Production Systems
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László Monostori, Zsolt Viharos, Hungarian Academy of Sciences, SZTAKI, Hungary

Schmitt, Robert (Germany)

Prof. Dr. Ing. Robert Schmitt, born 1961, completed his studies on Electrical Engineering with the specialisation on Communications Engineering at the Technical University of Aachen, Germany in 1989. Subsequently he became scientific employee in the Department of Metrology and Quality Management at the Laboratory for Machine Tools and Production Engineering. His focus of work lay in the field of production related Metrology and Communications Engineering in an automated environment. Later in Munich and in Austria he took leading positions in the field of Quality and Production.

He became Professor at the Technical University of Aachen on July 1, 2004. He has been Head of Department for Metrology and Quality Management at the Laboratory for Machine Tools and Production Engineering since September 2004 and became member of the Board of Directors at the Fraunhofer Institute for Production Technology where he is also Head of Department for Metrology and Quality Management. In 2010 he became Managing Director of the Laboratory for Machine Tools and Production Engineering.

Glöckner, Henrik (Germany)

Henrik Glöckner, born in 1982, is research assistant at the Chair of Metrology and Quality Management at the Laboratory for Machine Tools and Production Engineering of the RWTH (Rheinisch-Westfälische Technische Hochschule), Aachen University. The research area of Metrology and Quality Management operates within the scope of development and optimization of measurement processes and equipment, production-integrated metrology, quality control loops, quality management systems, as well as knowledge-, innovation- and optimization-management. His research activities focus on the field of Customer Satisfaction and Operations Management.

Content

DESIGNING CLOSED QUALITY CONTROL LOOPS FOR STABLE PRODUCTION SYSTEMS

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1 Abstract

To meet the challenge of producing innovative and technologically demanding products economically, companies need the ability of quick and flexible reaction to internal and external disturbances [1]. Increased performance of a company can be achieved by focussing on improvements to effectiveness and efficiency; principal tasks of modern quality management. As a result the companies' objective shifts from maximization of quality to a "controlled quality" aiming for the stabilisation of the operative and strategic value creation process. So the main problem of manufacturing enterprises is to dampen the oscillation of product, process and system quality caused by impacting disturbances and ineffective activities and measures due to fuzzy or uncertain information [2].

The paper proposes a new approach for the evaluation of the quality of entrepreneurial control mechanisms within production systems. Using the metrics and terms of control theory and cybernetics the organizational feedback processes can be developed further towards a blueprint for generic closed quality control loops.

The operative control level is characterized through three major stages executing a part of the quality control process: The sensor unit, which collects, filters and consolidates quality information and conducts a preliminary analysis of the resulting issues, the control unit, which selects and develops solutions for the identified problems and the actuator unit, tasked with the execution of the measures contained in the solutions. [3, 4]

The reference process description of the quality control loop is the basis for the further examination and feedback mechanisms, where the behaviour of quality loops is designed regarding the operational stability as the main performance indicator. Assisted by this methodology companies are able do identify and design their quality control loops.

2 Introduction

“It is not the strongest of the species that survives, nor the most intelligent. It is the one that is the most adaptable to change.”

- Clarence Darrow, famous American lawyer

Though CLARENCE DARROW originally did not address his sentence to the realm of entrepreneurial management but was referring to Charles Darwin and his findings in “*The Origin of Species*” the majority of companies discover its truth for themselves and their situation in today’s markets: They are currently facing global trends and inevitable consequences like individual and dynamic product demands and enhanced market restrictions in the long run, and have to deal with barely predictable constantly changing conditions from the planning level all down to the shop floor. Costly activities like fire fighting or specialized task forces are the result to cope with the consequences of the described internal and external dynamics [5].

To meet this challenge companies need proactive processes to improve and ensure planning dependability and moreover reactive workflows for quick and flexible reaction. This increased performance of a company can be achieved by focussing on improvements to effectiveness and efficiency; principal tasks of modern quality management. As a result the companies’ objective shifts from maximization of quality to a “controlled quality” aiming for the stabilisation of the operative and strategic value creation process.

The constituted problems are well known in the field of control theory. In order to cope with oscillation and disturbances in technical systems closed control loops are designed and parameterized following the targets of stability, disturbance compensation, desired value sequence, and robustness [6].

Though the mechanism of feedback are well known to the field of quality management as examples like the SHEWHART cycle (PDCA), the DMAIC-cycle of six sigma, or the ISO 9001 constitute, the structured design of control loops in companies and production systems is still a problem. As control theory proves – wrong or overhasty designed control loops tend to amplify the systems oscillations caused by disturbances and can even cause its collapse.

3 Background of Quality Control Loops

Due to their open and dynamic character, uncontrolled business processes with a lack of adequate feedback mechanisms tend to instability and chaotic development in case of unanticipated disturbances or target adjustments. This problem can be solved by the implementation of closed quality control loops.

A quality control loop can be characterized by its three main stages – the sensor unit, the control unit and the actuator unit [3]. Its general structure and the assigned tasks within the three major modules are derived from control theory respectively the German standard DIN 19226 [7]. However, the diversity of business processes requires applying control theory in a much broader sense. Mechanisms and functions of closed loop quality control are extended by principles of management cybernetics and failure management [2].

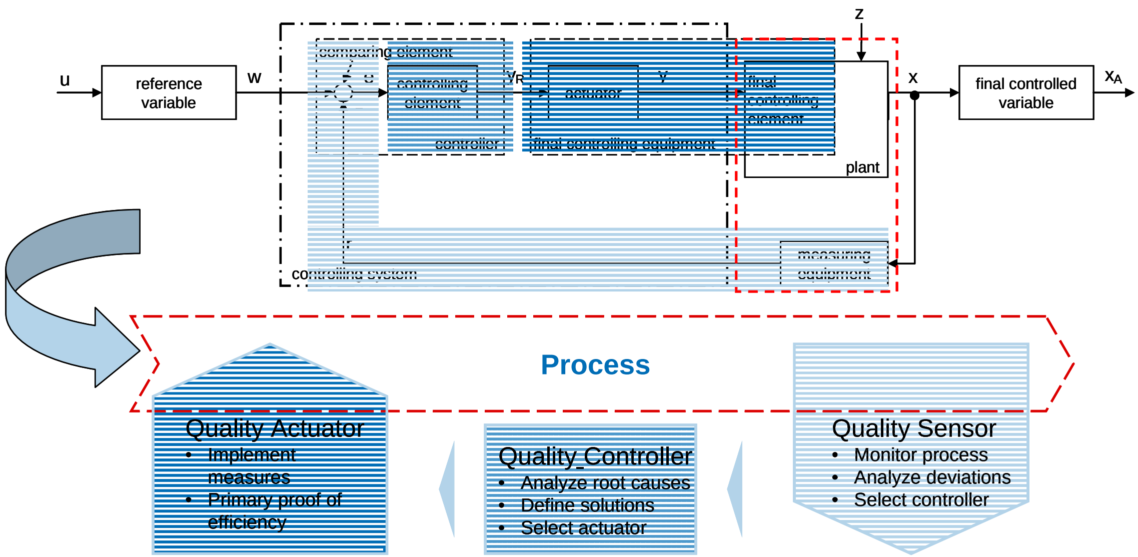

Figure 1: Derivation of Quality Control Loops from control theory

3.1 Quality Sensor

As the first stage of a quality control feedback mechanism, the quality sensor monitors the controlled variable and triggers an adequate controller in case of significant deviations from normal conditions. If being linked to the typical action diagram of a closed loop control (**Hiba! A hivatkozási forrás nem található.**), the rather technical tasks of the measurement equipment and the comparing element can be assigned to the quality sensor unit. Each sensor comprises a multitude of data acquisition units capturing raw quality data from various stages of the controlled system. The distribution of acquired data by the acquisition units is either constant with a defined frequency (e.g. KPI reporting) or event-driven. Examples of this second type of data acquisition units may include reports from employees, failure detection during QA spot test as well as customer complaints [1]. For further analysis a filtering, preparation and reduction of collected product or process data is being conducted by the quality sensor and subsequently being compared to a predefined target – in control theory referred to as reference variable. In case of a significant deviation an adequate quality controller has to be selected and informed, based on a pre-analysis of the identified problem.

3.2 Quality Controller

The main objective of a quality controller is the derivation and selection of adequate measures with regards to the problems identified prior by the sensor unit. In this context, reported problems are initially analyzed regarding their occurrence in the past and the existence of known measures for similar cases. On this basis, either existing measures have to be adapted to the current situation or completely new solutions have to be developed. To guarantee a closed action flow and to allow for stable system behaviour, escalation routines, timing parameters and well designed sets of standardized measures have to be defined for each quality controller within a company. Based on the selected solutions an appropriate quality actuator is assigned by the control unit and informed about the measures to be implemented.

3.3 Quality Actuator

The quality actuator is the executive unit which implements the afore-mentioned measures within the controlled process and thus closes the quality control loop. Additionally the actuator is responsible for providing a primary proof of efficiency. Hence the main task of the actuator is the operationalisation of solutions provided by the controller.

Should the implementation of a solution fail to meet the objectives, measures can either be adapted by the quality actuator himself or the responsibility is delegated according to well defined escalation routines. This may include the reselection of the actuator, the measure or both. A long term evaluation of the realized measures is – due to the closed loop character – constantly provided by the quality sensor's monitoring of the controlled variable.

4 Quality Control of Business Processes

Quality Control loops can manifest different characteristics and structures due to their purpose. While some of them have an informal nature – even a coffee break can serve the purpose of a quality control loop - others follow standardized work-flows and descriptions as for example the complaint process.

Quality control loops can be categorized as to their organizational levels they interact with. Therefore horizontal and vertical control loops are differentiated:

Horizontal control loops are always located on one organizational level. They describe how a single element of one level is controlled and how the control loops of this level communicate and interact. An example for a control loop on shop floor level can be end-of-line inspections within the production, customer complaint and problem management processes for the order fulfillment or review meeting within product development processes. Processes which are necessary for the management and planning of the business processes such as production or quality planning are attributed to the planning and control level while the strategic level provides control loops for the alignment of the entire production chain.

Vertical control loops adhere between at least two different levels and describe how the control loops of the lower levels are monitored, controlled and designed as for example a management assessment of business processes.

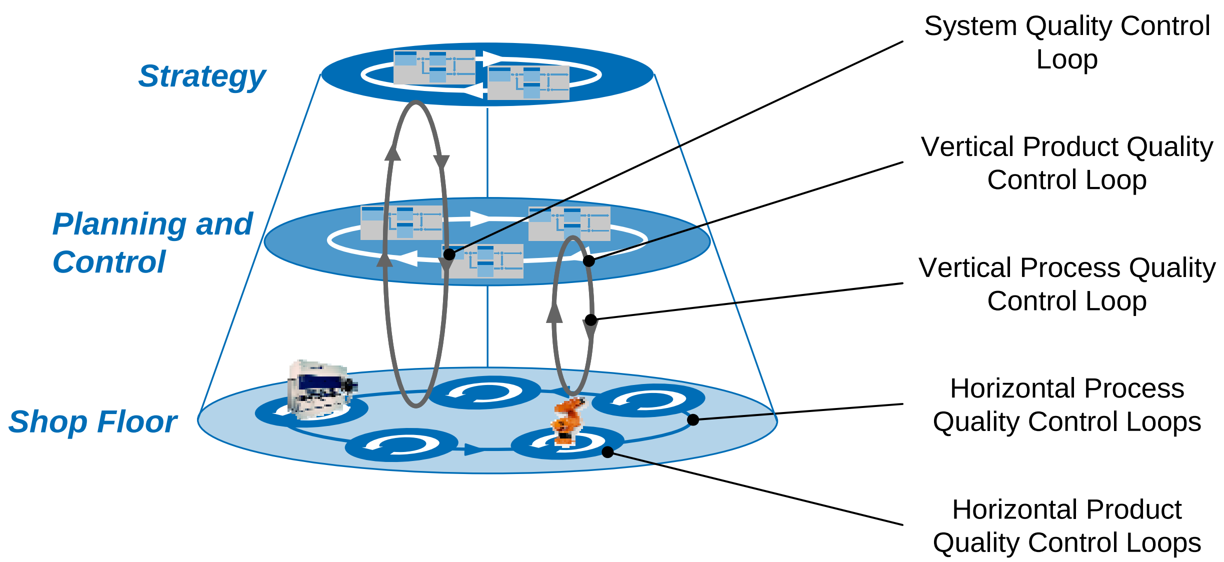

Figure 2: Horizontal and vertical Quality Control loops on organizational levels

5 Identification and Description of SME's Quality Control Loops

A vast majority of producing companies in Europe, especially small and medium enterprises (SME), are currently not in a state of having implemented efficient closed quality control loops, yet they implicitly have a huge amount of interconnected quality sensors, controllers and actuators. As part of the research project (QC)² "Quantifiable Closed Quality Control" a process reference model for quality control loops has been developed.

According to ROSEMANN the main objective of a reference model is "to streamline the design of enterprise-individual (particular) models by providing a generic solution" [8]. Hence reference models are blueprints of best practice, which accelerate the modelling of individual processes by providing a set of potentially relevant processes and structures [9, 10].

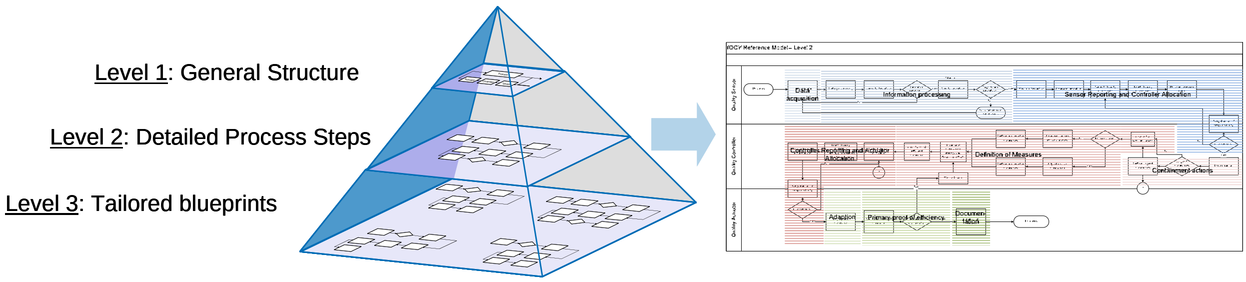

Figure 3: The (QC)² process reference model

The (QC)² reference model for closed loop quality comprises three levels of decomposition detail (Figure 3). The first and most abstract level defines the universal structure of a quality control loop with its three main elements: the sensor, the controller and the actuator, as described in the previous chapter. The (QC)² reference process consists of nine main phases:

- Data acquisition
- Information processing
- Sensor reporting and controller allocation
- Containment action
- Measure definition
- Controller reporting and actuator allocation
- Adaption
- Primary proof of efficiency
- Documentation

The second level of the reference model delivers a generic but detailed description of all relevant process steps (activities, decisions, inputs and outputs) within the scope of closed loop quality control. Based on this generic process model companies are capable of identifying, describing and optimizing the structures of their existing quality control loops and even designing completely new processes by means of “design by reuse”. Providing a reusable and efficient design with specified subprocesses, the reference model accelerates the modelling process of enterprise-individual quality control loops.

The third level of the reference model provides tailored blueprints of recommended quality control loops for selected processes of SME's order fulfilment.

Each quality control loop of a company can be described and modelled by adapting the reference model to individual needs and constraints. Furthermore the reference model provides the basis for the $(QC)^2$ software with its integrated quality control loop assessment tool.

6 Requirements of SME for quality control loops

In order to collect the requirements for the design of the reference and assessment model for quality control loops a number of small and medium-sized Hungarian and German companies were interviewed. In order to collect these requirements and to formalize the introduced quality control loop description a questionnaire was prepared.

The template was developed in order to guide the user through the identification process of quality control loops and to capture the entrepreneurial requirements. Firstly the user has to define the system in focus and the related elements existing in his company according to the general architecture of control loops. Second, the specification of the control functions in form of cause-and-effect chains connect the output and input parameters with each other. Further the impact of disturbances on control loop elements are asked in order to explore e.g. the stability and controllability of the quality control loop. The next part of the questionnaire analyzes the timing features of the loop like delays in measuring output values, having delays in control feedback or in the changing of the input parameters by the actuator(s) of the loop. With this methodology in mind, users were finally asked how they would estimate the benefit of the reference model and assessment tool for quality control loops and where they would like to implement control loops within their companies.

Since many different control loops exist in organizations a prioritized list of fields where the control loop methodology is most likely to be applied based on the interviews was defined. The targeted control loops are related to the main business process of the companies divided in development, order fulfillment and sales. Based on the process reference model blue prints will be developed which tailor these main business processes on level 3.

7 Qualitative und quantitative assessment of Quality Control Loops

As part of the afore-mentioned (QC)² process reference model, “base practices” for each process step are documented correspondent to the SPICE process assessment [11]. Based on the process reference model an assessment tool is currently being developed within the frame of this research project. The method will allow organizations to assess the closed loop quality control of individual business processes based on qualitative and quantitative characteristics.

A self-assessment of closed loop quality control is conducted on three main levels. The first level (level 1: performed) provides a qualitative assessment of individual quality control loops based on the “base practice” process description. For this purpose a detailed questionnaire has been developed, which determines the degree of performance regarding each process step of the reference model with regards to the analyzed process. Hence weaknesses in the structure of a quality control loop as well as in the individual degree of fulfilment of each reference model’s process step can be identified by a company itself even without a profound knowledge of control theory and quality management.

The second level of the assessment model determines whether the analyzed quality control loop is “managed” (level 2: managed). This includes a quantitative assessment of the quality control loop based on KPIs. The quantitative evaluation considers among others a range of timing parameters such as dead time (delays within the process), costs and resource requirements. With regards to the stability of a closed loop controlled system, dead time is one of the most challenging dynamic elements that occur in most quality control loops. Thus one of the main goals of the quantitative analysis is the identification of inherent time delays.

On the third level of the assessment model (level 3: established), the overall maturity level of quality control – the system quality – is being examined. The main question to be asked here is whether quality control loops are implemented for all main business processes and whether they are analyzed and improved continuously.

Subsequently the process reference model as well as the quality control loop assessment tool will be implemented into a software program. SME will be able to register online for the use of the web-based program which allows a firm-specific adaptation of the generic blueprints as well as the design of completely new quality control loops based on the second level of the (QC)^2 reference model. Appointed quality control loops can furthermore be analyzed with the aid of the assessment tool as one module of the software program. The software will provide an online platform with an open discussion forum for companies that are motivated to share and discuss their own quality control loops as well as those, that want to access and discuss best practice examples.

8 Conclusion and acknowledgements

A core element of companies in order to cope with change and disturbances in business processes are feedback mechanisms. The structure and conduct of quality control loops can stabilize the processes by dampening the product and process quality from oscillations caused by disturbances. As characteristic elements of these mechanisms quality control loops serve as the basic model for the identification, simulation, improvement and implementation of feedback structures within companies. The further research will challenge the design of a process reference model and the conception of various blueprint models for quality loops in order to simulate and assess the systems performance.

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