

DESIGNING AN E-BASED REAL TIME QUALITY CONTROL INFORMATION SYSTEM FOR DISTRIBUTED MANUFACTURING SHOPS

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Abstract: Advanced manufacturing systems need to be developed for an enterprise to survive in the increasingly competitive global market. Statistical e-based quality control approach combines statistical quality analysis and reporting capabilities with web technology to deliver process optimization solutions. In this paper we develop a structured profile for statistical e-based quality control to provide the capacity to access required data anywhere. It helps enterprises to develop customized quality information systems, create and distribute reports via the internet, and provide real-time display of quality profiles for process monitoring. Quality engineers and managers have been dependent on information system (IS) departments to secure access to such data. Statistical e-based quality profile is designed to bridge the gap between the raw data and genuine quality improvement efforts by providing a powerful web-based solution for real-time quality process.

1 INTRODUCTION

The global diffusion of advanced manufacturing systems naturally resulted in the needs for distant product development, which in turn requires the provision of production information and control on its procedures across product life cycle. In a distributed manufacturing shop (DMS), factories possessing various machines and tools are at different geographical shop floor, and different manufacturing capabilities are often selected to achieve the highest production quality. Manufacturing operations can be performed by different machines and tools at different locations. Distributed manufacturing enables the enterprises to achieve better product quality, lower production cost and reduced management risk.

Quality information system (QIS) controls the quality related information flow between the shop floors that are combined in a production network in a geographically distributed manufacturing shops as shown in Figure 1.

Implementation of a distributed quality information system requires the data gathering, processing, storage and distribution among any shop floors and central control office. In response to this

need, the research community has come with a solution called e-Based DMS, which is defined as “an Internet-based computational architecture that supports the sharing and transfer of knowledge and information about the product and manufacturing process amongst geographically distributed shops” (Rodriguez and Al-Ashaab, 2002; Molina et al., 1995; Ka Chi Lam and Thomas Ng., 2006).

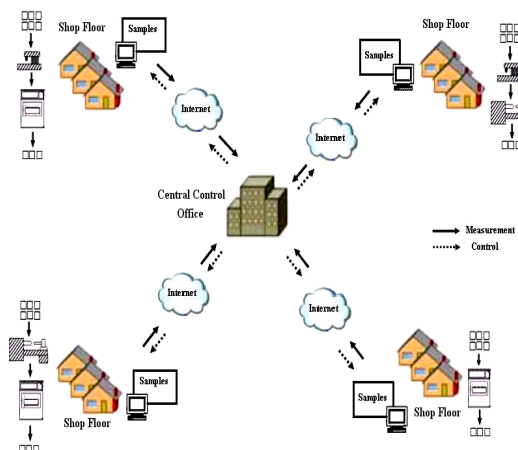


Figure 1: The distributed manufacturing shops (DMS).

The aim of this paper is to improve the quality of production and reduce loss through systematic tracking and the use of information as continuous feed-back to production lines by central control office through a real time quality control information system (RTQCIS). The proposed paradigm is to aid quality engineers in distributed shops to send data and obtain reliable results pertaining to manufacturing. The RTQCIS architecture also satisfies all the fundamental requirements for DMS about statistical quality control in a real time environment.

2 STATISTICAL E-BASED QUALITY CONTROL FOR A DMS

In general, an internet-based manufacturing system must consist of all processes related to shops (Sangyoon et al., 2004). The work-pieces in shop are processed in the sub-processes until the final product is obtained. In each sub-process the work-piece quality must be measured. This system must be connected to internet (or any world-wide information area network) according to Figure 2.

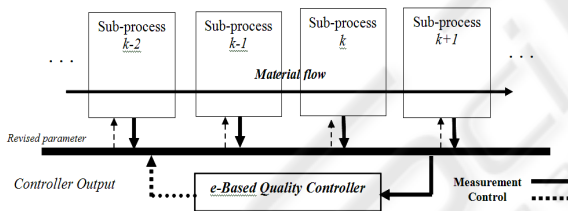


Figure 2: The model of e-based manufacturing sub-processes.

Statistical e-based QC has combined statistical quality analysis and reporting capabilities with revised policy over web to deliver a process optimization system that will give everyone in an enterprise (from the manufacturing floor to the central executive suite) the information they need to monitor, analyze, and improve important processes. Statistical e-based QC must be designed to help enterprise to bridge the gap between the raw data and genuine quality improvement. It must provide a powerful web-based solution for real-time data to be shared anywhere in the enterprise any time in a secure environment.

Quality managers have used quality control systems such as statistical process control,

production part approval process, failure mode effects analysis, gage calibration and document control to access key attribute of production process.

Manufacturers currently measure process key parameter and performance to improve quality in production (Vijayaram et al., 2006). Statistical e-based quality control enables continuous quality improvement through easy and cost-effective access to quality data. It requires an internet-enabled software solution to allow individuals to access the quality data for various analysis. It also needs a dynamic web-based application that serves as a quality portal, so that users can easily and cost-effectively integrate a wide variety of information for quality improvement.

Any internet-based system architecture is structured around a three-layered framework: information, application and end user layer (Rodriguez and Al-Ashaab, 2005). The end user layer is connected to the application web server (application layer), which in turn is connected to the information databases (information layer). The application layer consists of two elements: decision support applications and information management tools. The web-based interface of the end-user layer helps users to view and use different decision support applications and tools. The product data is produced and used by different engineering applications throughout the entire production processes.

For implementing such a system, we need a client-server architecture that allows the appropriate database management system (e-Server) to be connected to the quality control database in information layer as shown in Figure 3.

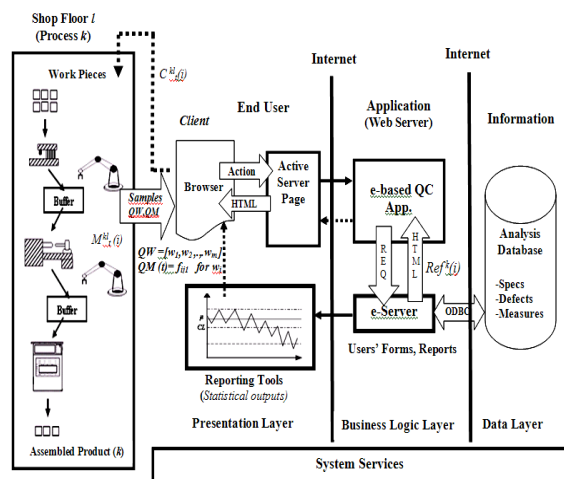


Figure 3: Client server architecture.

Statistical e-based quality controller utilizes statistical e-server to perform all data access, transformation, analyses and output creation.

e-Server is a module used for statistical analysis and seamless integration of new or existing applications. Users request an action from within the graphical user interface in a browser (the presentation layer) by hitting a button, selecting a menu or completing a form. Once the request is received by the presentation layer, the presentation layer (Active Server Pages) handles the request and directs it to the application (Business Logic Application layer) for processing. The application processes the request and determines appropriate actions needed to complete the request via interaction between e-based quality control application and e-server. For computation, analysis and graphics (SPC charts), the application analyses data with the help of database to response the request via ODBC tools. After directing the requests to this platform, computations performed and results return in the form of HTML table or data file to the reporting tools (i.e. accept data from the application, process the request, generating an SPC chart, and return the resulting graph in the form of image file or HTML, check SPC rules and make alarm by sending rule violation information to the application).

It should also be able to perform real-time display of quality control charts to monitor processes. It should be a flexible, full-featured analysis required for continuous quality improvement. Data preprocessing procedure for customer analysis tracks various online activities of customers. This involves capturing information about individual user, constructing logical user "session", and creating key terms or variables. For a DMS, our model captures key terms of the quality information on assembled products (*AP*), sub-assembled products (*SAP*) and parts or components (*P*). To implement a mathematical model of e-QC layer, we present internal blocks of e-based quality control module as shown in Figure 4.

In order to supply the controller itself with the complete information about the current process state, a detector unit is introduced which receives the measurement $M^{kl}(i)$ for frequency of n times, and passes the state information $S^{kl}(i)$ to the controller. The measurement at the end of each sub-process is received only in the step of the work-pieces that are passing through and the control output is determined. (Where k is sub-process number, l is location number, i is attribute number and t is time

period). The control problem is now to find a controller output $C^{kl}(i)$. In general, this may need a sequence steps until $Ref^{kl}(i)$ can finally be reached. A process is called controllable in one step for any given state $S^{kl}(i)$, if the measurement $M^{kl}(i)$ can reach the reference value $Ref^{kl}(i)$ such that:

$$\lim |Ref^{kl}(i) - M^{kl}(i)| \rightarrow 0$$

3 STATISTICAL QUALITY PROFILE

In this section, a mathematical model is introduced to provide a real time display of quality profile. The following notations are considered.

Notations:

w_i	attribute i
$M^{kl}(i)$	measurements vector at time t in shop floor l for process k on attribute i
$S^{kl}(i)$	state information at time t in shop floor l for process k on attribute i
$Ref^{kl}(i)$	reference value for process (product) k on attributes i
f^{kl}_{ijl}	frequency of quality key attribute i for process k at location l in product j
$LSL^k(i)$	lower specification limit for process k on attribute i
$USL^k(i)$	upper specification limit for process k on attribute i
LCL^k	lower control limit for process k
CL^k	central control limit for process k
UCL^k	upper control limit for process k
σ_k	Standard deviation for process k
M	number of key attribute
N	number of products
P	number of locations
T	time period duration
$C^{kl}(i)$	control chart vector $[LCL^k, CL^k, UCL^k]$ at time t in shop l for process k on attribute i

The quality information is captured individually for each part and compiled collectively from the set of assembled or sub-assembled products. As a result of tracking the quality of each product, we obtain the vector of comprehensive key terms or key words on quality; $QW = [w_1, w_2, \dots, w_m]$. The quality information is collected through electronic customer interaction on the web. We define $QM(t) =$

$\lfloor f_{ijl} \rfloor_{m \times n \times p}$ as a quality space at time t , where f_{ijl} is the frequency of quality keyword i related to product j and location l . We also define $FQM(t) = \lfloor \alpha_{ijl} \rfloor_{m \times n \times p}$ as a fuzzy quality space at time t , where α_{ijl} is a corresponding keyword-product-location fuzzy membership value as shown in formula (0).

$$\alpha_{ijl} = \frac{f_{ijl}}{\sum_{i=1}^M f_{ijl}} \times \frac{f_{ijl}}{\sum_{j=1}^N f_{ijl}} \times \frac{f_{ijl}}{\sum_{l=1}^P f_{ijl}} = \frac{(f_{ijl})^3}{\sum_{i=1}^M f_{ijl} \sum_{j=1}^N f_{ijl} \sum_{l=1}^P f_{ijl}} \quad (0)$$

The ratio $\frac{f_{ijl}}{\sum_{i=1}^M f_{ijl}}$ can be viewed as a reliability value

for quality keyword w_i in the product-location incidence matrix, and the ratio $\frac{f_{ijl}}{\sum_{j=1}^N f_{ijl}}$ as a reliability

value for product j in the keyword-location incidence matrix, and the ratio $\frac{f_{ijl}}{\sum_{l=1}^P f_{ijl}}$ as a reliability

value for location l in the keyword-product incidence matrix, and finally α_{ijl} will be the reliability of quality information in the quality keyword-product-location space. Tracking by time could produce a set of fuzzy values: $\alpha_{ijl}(T) = [\alpha^1_{ijl}, \alpha^2_{ijl}, \dots, \alpha^T_{ijl}]$. This vector shows the profile of the quality space. For sub-assembled products (SAP), the final fuzzy value is $\alpha_{ijl}(SAP) = \min \{ \max \{ \alpha_{ijl}(p) \}, \alpha_{ijl}(SAP) \}$. Where $\alpha_{ijl}(p) \in \alpha_{ijl}(SAP)$ as a required components to SAP. For assembled product (AP), the final value is considered as: $\alpha_{ijl}(AP) = \min \{ \max \{ \alpha_{ijl}(P) \}, \max \{ \alpha_{ijl}(SAP) \}, \alpha_{ijl}(AP) \}$, where $\alpha_{ijl}(P)$ and $\alpha_{ijl}(SAP)$ are immediate predecessor to AP. As for quality key terms, the formulation (1) is used for an individual location and formulation (2) for a combination of locations.

$$CL = \frac{\sum_{t=1}^T \alpha_{ijl}^t}{T} \quad (1)$$

for $j = 1, 2, \dots, n$

$$CL = \frac{\sum_{t=1}^T \sum_{l=1}^P \alpha_{ijl}^t}{T \cdot P} \quad (2)$$

for $j = 1, 2, \dots, n$

As for quality on total attributes, we consider formulation (3) for an individual location and formulation (4) for a combination of locations.

$$CL = \frac{\sum_{t=1}^T \sum_{i=1}^M \alpha_{ijl}^t}{T \cdot M} \quad (3)$$

for $j = 1, 2, \dots, n$

$$CL = \frac{\sum_{t=1}^T \sum_{i=1}^M \sum_{l=1}^P \alpha_{ijl}^t}{T \cdot M \cdot P} \quad (4)$$

for $j = 1, 2, \dots, n$

As a result of tracking the quality profile, the Equations (5) and (6) are used for obtaining process control limit.

$$UCL^k = CL^k + 3\sigma_k \quad (5)$$

$$LCL^k = CL^k - 3\sigma_k \quad (6)$$

Where σ_k is the standard deviation of process k . The controller applies the control chart vector as given in Equation (7).

$$C_i^{kl}(i) = [LCL^k, CL^k, UCL^k] \quad (7)$$

The statistical reports are drawn graphically by e-Server on internet browser of shop floor and quality engineer could achieve the appropriate policy.

4 DISTRIBUTED QUALITY MANAGEMENT USING EVOLUTIONARY ALGORITHM

Quality management for an enterprise wide e-based QC system focuses on analyzing data to make decisions that affect future production and revenue. The analysis includes real-time enterprise wide view that identifies the levels of operations, and batch report according to predetermined time period. We

can apply the evolutionary rule to automatically modify the structure of e-based quality information. It updates the quality profile in a dynamic fashion. The following steps are suggested as an evolutionary algorithm.

Step 0. Set $T=0$.

Step 1. Obtain the quality information profile using e-QC.

Step 2. Apply distributed quality management and quality decision making policy to modify quality structure.

Step 3. Implement feasibility analyzer for quality decision-making.

Step 4. Set $T=T+1$.

Step 5. Update the e-based quality network profile and go to step1.

As time passes, new attributes in the quality information space profile can be generated. In the newly generated profiles, some attributes may take a value beyond the lower or upper bound of the range of variables appropriate for quality decision-making. Then the feasibility analyzer is used to check the feasibility boundary of attributes. New attributes are collected and stored to form a meta-decision support.

5 CONCLUSIONS

In this paper, we introduced a framework of e-based quality management and developed a new formulation that would provide a web-based solution for real time control of a process. The suggested logic is useful when we want to use a wide variety of quality characteristics as key attributes. As a result of using statistical e-based quality profile, anyone in an enterprise can contribute to quality improvement efforts. Web-enabled quality control system will present an extensive connectivity outside a plant. A customer's engineer could tour the plant site and check the profile online. It is used mostly within a factory today, but after some advancement, and with the process in place, access to quality data will be extended across the supply chain and to customers. One should be able to obtain information about the batch s/he ordered and see how it conforms to the specifications. Based on the research and framework

done in the distributed manufacturing systems, we developed an analytical approach on e-based quality control. For a customer interface and reliable and sustainable information provision, an evolutionary algorithm is suggested using evolutionary rule. The prototype of eRTQCIS-DMS has been demonstrated that quality management data can be captured, stored, retrieved and disseminated through a web-based system.

The internet technologies also facilitate the sharing of quality management information in a seamless manner. Reports containing consolidated quality management information can be generated by eRTQCIS-DMS. With those information and reports, manufacturer would have a better understanding about the product quality and performance evaluation. A mathematical model for an e-based statistical control on the basis of e-based quality profile can be elaborated in future researches.

REFERENCES

- Ka Chi Lam, S. Thomas Ng., (2006). A cooperative Internet-facilitated quality management environment for construction, *Automation in Construction*, 15(1), 1-11.
- Molina, A., Al-Ashaab, A., Ellis, T., & Young, R. (1995). A review of computer-aided simultaneous engineering systems. *Research in Engineering Design*, 7, 38-63.
- Rodriguez, K., & Al-Ashaab, A. (2002). A review of internet based collaborative product development systems. *Proceedings of the International Conference on Concurrent Engineering: Research and Applications, Canfield, UK*.
- Rodriguez, K. & Al-Ashaab, A.(2005). Knowledge web-based system architecture for collaborative product development, *Computers in Industry*, 56, 125-140.
- Sangyoon C., Kyungrai Kim, Yea-Sang Kim. (2004), A process-based quality management information system, *Automation in Construction*, Vol 13, 241-259
- Vijayaram, T.R. , Sulaiman, S. Hamouda A.M.S. , Ahmad, M.H.M. (2006) , Foundry quality control aspects and prospects to reduce scrap rework and rejection in metal casting manufacturing industries , *Journal of Materials Processing Technology*, 178(1-3), 39-43.