An Automatic Online System for Detecting and Analyzing Quality Data of Products in Manufacturing Process

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Abstract. As the business volume is getting bigger, more and more problems are exposed to product quality testing. For example, the application of the traditional statistical process control (SPC) is not flexible on different occasions due to the fixed testing rules and the manual data collection. These problems lead to large deviation and low efficiency. In order to fasten the testing process and optimize the results of testing, we design an online system that integrates the Drools rule engine and automatic collection mechanism based on some communication protocols and devices into SPC to replace traditional manual quality testing. In this paper, we introduce the principle of the system design in detail. The experimental results show that we can utilize SPC in a more convenient and efficient way.

1. Introduction

During the process of manufacturing, production detecting is an indispensable link. However, the disadvantages and limitations in traditional SPC are exposed with the appearance of some intellectual testing way. The working principle of the traditional SPC system is that record original data in a notebook after manual testing, then compute the recorded data manually, which is an out-dating working pattern and with low working efficiency and high cost of the resources of humans and computing. In addition, in the long-term work, the heavy workload and high demand about accuracy and security make staff feel exhausted and neglect some fatal details. Therefore, a practical system is urgently needed to meet the requirement of modern production.

Compared with the traditional SPC, we design another SPC scheme which is suitable for the manufacturing process. It automatically collects data from quality detecting by using relevant devices and computes inside the system.

In the system, the rule engine mechanism separates business logic and programming code so that it meets the requirement of formulation and modification of detecting rules, which leads the system to be decoupled and more easily maintained.

In this paper, we mainly introduce the principle about designing the system based on SPC and core technologies to detect and analyze the data of quality. In the following sections, we discuss previous work related to the automatic collection, usage of SPC, and system rules making in Section 2. Section 3 presents the work process of SPC. In Section 4, we propose principles of system design. The results of system experiments are presented in Section 5. We draw a conclusion in Section 6.
2. Related work

2.1. Automatic Collection
Information collection is a great part of system analysis. However, manually collecting is not adaptive to the increase in business volume due to the low efficiency and large deviations. In addition, the use of automatic equipment has been universalizing. The technology of automatic collection can sort and analyze quality data in real-time to improve working efficiency [1]. Several ways of automatic information collection are formed in various fields. Francesco Piras et al. did some researches about data collection about travel behavior in [2]. Yaru Zhang et al. proposed the automatic collection and management system of the device information based on the convolutional neural network in [12]. Automated collection was also used in enterprise architecture models [3] and crystallography [4, 5].

2.2. Applications of SPC
Statistical process control (SPC), a process-controlling tool, which is used to collect product data and analyze the production process and take some measures to eliminate affections to keep process of productions under the control.

In early research, Ben Mason et al. revealed the limitations in the process of quality detection through [6], which is examining the qualification of products only when the production is completed. But for unqualified products, they need to be scrapped or reworked, which means that the costs of production or reprocessing are wasted in the production process.

In addition, Atle Fretheim et al. found in [7] that some interventions exist during the usage of SPC and it is difficult to evaluate the influence of interventions. They proposed a way called interrupted time series (ITS) to quantify the trend and situation before and after intervention in a statistical way and evaluate whether the estimated difference is statistically significant.

Nowadays, SPC has been applied in more and more fields, such as the service industry [6], healthcare industry [9, 13], Pharmaceutical industry [8] and etc.

2.3. System rules making
In manufacturing, the completion of products needs multiple machines and multiple processes, and the relationship between these processes needs to be defined by rules. In discrete manufacturing, advanced planning and scheduling (APC) was designed to solve the optimization scheduling problem of multiple processes and multiple resources. APS systems provides a way in making rules and resources allocation [10].

3. Work process of SPC
The components impacting key processes consist of common causes and special causes: in the process, the common causes have many variations with a stable and repeatable distribution; the special causes are unpredictable in the process. SPC control chart should be applied to key processes and lower the influence of the common causes to the greatest extent. Therefore, the implementation of SPC should identify the key process at first.

There are many features in the application of SPC: 1. Customer-specified features; 2. features regulated due to the principle of security; 3.the features specified by companies in the manufacturing process and so on. In the manufacturing process, it is difficult for us to evaluate all aspects of the features. Therefore, we have to follows the 80/20 law of Pareto [11] to select features with greater impacts.

Thanks to the influences of various factors, the product quality always changes, which the phenomenon is called “fluctuation”. Fluctuation cannot be eliminated, but can be predicted and under control through SPC. At first, we need to choose a suitable control chart according to the characteristics of process and adjust machines to make factors (e.g. people, machines, material, methods, environment and measuring) under control. Therefore, we should compute statistical data within control chart in real time.
Finally, when it is found that the products are abnormal, we have to analyze the causes in time and take measures to restore to the normal process.

4. System framework and implementation

4.1. System architecture

The system architecture has been shown in Figure 1. There are six layers in this system, system presentation layer, application layer, platform layer, edge computing layer, data adaptation layer, and equipment inspection. The system presentation layer belongs to the visualization module, the system integration module includes the application layer, the platform layer. The rest of the layers belong to the protocol integration module.

- System presentation layer. It is user-oriented and includes some visual interface presented in applications and webs and serves the interface between the system and the user.
- Application layer. It can process data collected from quality inspection and then generate product process index and related control charts to provide services for capability analysis of product process.
- Platform layer. It provides a series of function interface for the implementation of systems so that the system can realize the functions of computing and storage: it provides parameters required by the application layer and receives the data from the lower layer and stores them in the database. In addition, the platform layer includes the Drools rule engine so that the system can greatly improve the re-usability by formulating testing rules in SPC.
- Edge computing layer. The edge computing layer can realize functions such as data standardization, data encryption/decryption, etc. It can process data in time without heavy transmission and reduce the consumption of system resources. Furthermore, this layer prompt the system to cooperate with other low-latency equipment.
- Data adaptation layer. It provides some communication protocols including OPCUA/OPCDA and TCP/IP and serial communication interfaces RS232, RS485 which are based on Modbus protocol.
- Equipment inspection. In this layer, some equipment is used to realize product detection.

![The system framework](image)

Figure 1. The system framework

4.2. Automatic collection

Automatic collection is a distinguishing characteristic of our system. It is designed to improve the efficiency of collecting mass quality data in discrete manufacturing. We show the architecture of automatic data collection in Figure 2. In the architecture, we divide data collection into 3 layers. The data storage layer consists of various databases used to store data from message-oriented middleware.
Message-oriented middleware achieves data collection, classification, and circulation. The data acquisition layer includes sources and the means of data acquisition.

The automatic collection mechanism consists of message queue, industrial detecting devices, communication protocols, and MQTT message-oriented middleware.

- **Message queue.** The message queue is one of the important components in a distributed system, as a container used to store messages, it helps us decouple the system if we store data in the message queue. Besides, the asynchronous switch can also be achieved because business logic in the system runs asynchronously with the help of the message queue.

- **Communication protocols and industrial devices.** Data collection relies on a variety of industrial detecting devices which are based on several communication protocols such as PLC, OPC, RS232, RS485, Modbus, and so on. The data communication has a universal standard between hardware and software thanks to these protocols. In the data adaption layer, the internal protocols are compatible with hardware protocols and open API for hardware, when devices collect quality data from products, they can transfer data through Communication protocols to our system if they are in same local area network (LAN) so that our system can achieve the capability of automatic collection and uploading.

- **MQTT message-oriented middleware.** The middleware, based on publish-subscribe mode, enables messages to be published in a one-to-many way and reduces applications coupling. Furthermore, it can asynchronously clean data collected from industrial devices.

4.3. *The usage of Drools rule engine in SPC*

Shewhart proposed the “Shewhart control chart” to monitor some key features and an abnormal conditions found in the process so that we can optimize production processes. To illustrate how to meet the needs of different occasions of the control chart, the Drools rule engine is introduced here.

**Figure 2. The architecture of automatic data collection.**

**Figure 3. The work flow of the rule engine in our system.**
The Drools rule engine, a component embedded in applications, is one of the rule engines which are variable and separate rule sentences from programming code, then store them in files as rule scripts. It not only achieves that business program and rules are individually managed but also frees variable and complicated rules from applications and even makes the changed rules immediately effective and put into use rather than modifying codes or restarting machines.

We exhibit the work flow of the rule engine executing in our system in Figure 3, the definition and modification of rules is stored in an individual module, when application program interface (API) receives data, the system will call and perform relevant rules to judge the rationality of data and return the results to the system.

5. Experiments
In this section, we do an experiment using this system and show in Table 1 and Figure 4. Meanwhile, we present the experimental results of our system via Figures. Through the system, we realize the automatic collection and analysis of product data. We implement the development of the system in C# language and carry out all experiments in the environment of Intel i5 3.3GHz Core with 8G memory and 256G Solid State Disk running in Windows 10. In our system, we set several rules and choose some of them to meet the various needs of quality testing.

Table 1. The selection of rules for judgment

| Number of Rules | The Using Rules | Bases of Rules |
|-----------------|-----------------|----------------|
| ☑ R0            | Exceeding the specification limits | Exceeding the specification limits |
| ☑ R1            | A point locates out of the area of Triple sigma | [n] point locates out of the area of [m] times sigma |
| ☑ R2            | The 9 continuous points locate on the same side of the center line | The [n] continuous points locate on the same side of the center line |
| ☑ R3            | The 6 continuous points increase/decrease by degrees | The [n] continuous points increase/decrease by degrees |
| ☑ R4            | The 14 continuous points distribute up and down alternately | The [n] continuous points distribute up and down alternately |

Figure 4. The process and experimental results of the system execution

Based on the design mentioned in the above sections, we develop the system and apply it to the detection of sample data. First, we set the fixed parameters such as USL, LSL required by analysis of samples, and choose judging conditions as Table 1 shows, which have been set based on rules engine in the system as detecting rules in advance. Then we collect specification parameters of products and upload them to the database of our system.
As Figure 4 shows, Inside the system, the calculation of relevant parameters (Cpk, Ca, Cp, Ppk, etc.) is completed thanks to the embedded algorithm, and show several analysis charts (control chart, Cpk analysis chart, samples execution chart, etc.) in the main interface. And the status of a group of data is also presented which is according to judging rules, then the system will record uncontrollable information for administrators to make the solution.

6. Conclusion
In this paper, we design an online system of detecting and analyzing quality data. Comparing with traditional detection and analysis system, it is based on statistical process control that can inspect the product quality in the process and improve defective ones. In addition, we add the technology of the Drools rule engine and automatic collection into the system. With the Drools rule engine, the users can set detecting rules adapted to their requirements, which improve the re-usability of our system. And in discrete manufacturing, automatic collection mechanism reduces many complicated manual steps and gets the efficiency of product detecting enhanced. From what has been proposed in this paper, this system is effective and adaptive to different occasions.

References
[1] Ingemansson A, Ylipää T and Bolmsjö G S 2005 Reducing bottle-necks in a manufacturing system with automatic data collection and discrete-event simulation J. Manuf. Technol. Manage. 1 pp.615-28
[2] Piras F, Sottile E, Calli D and Meloni I 2018 Automatic data collection for detecting travel behavior: the IPET platform Procedia Computer Science 134 pp.421-6
[3] Holm H, Buschle M, Lagerström R and Ekstedt M 2012 Automatic data collection for enterprise architecture models Software and Systems Modeling 13 pp.825-41
[4] Minor W, Cymborowski M and Otwinowski Z 2002 Automatic system for crystallographic data collection and analysis ACTA PHYSICA POLONICA A 101 pp.613-19
[5] Svensson O, Gilski M, Nurizzo D and Bowler M W 2018 Multi-position data collection and dynamic beam sizing: recent improvements to the automatic data-collection algorithms on MASSIF-1 Acta Crystallogr. Sect D: Biol. Crystallogr. 74 pp.433-40
[6] Mason B and Antony J 2000 Statistical process control: an essential ingredient for improving service and manufacturing quality Managing Service Quality: An International Journal 10 pp.233-8
[7] Fretheim A and Tomic O 2005 Statistical process control and interrupted time series: a golden opportunity for impact evaluation in quality improvement BMJ Quality & Safety 24 pp.748-52
[8] Fasting S and Gisvold S E 2003 Statistical process control methods allow the analysis and improvement of anesthesia care Canadian Journal of Anesthesia/ Journal Canadien D'anesthésie 50 pp.767-74
[9] Vincent C A 2005 Analysis of clinical incidents: a window on the system not a search for root causes Quality and Safety in Health Care 13 pp.242-3
[10] Montesco R A E, Pessoa M A O and Blos M F 2015 Scheduling heuristic resourced-based on task time windows for APS (Advanced planning and scheduling) Systems IFAC-PapersOnLine 48 pp.2273-80
[11] Kheybari S, Najj S A, Rezaie F M and Salehpour R 2019 ABC classification according to Pareto's principle: a hybrid methodology OPSEARCH.
[12] Zhang Y, Gong X, Que X and Tian Y 2019 Automatic Collection and Management System of Computer Room Assets based on Convolutional Neural Networks ITATC2019 pp.258-62
[13] Imam N, Spelman T, Johnson S A and Worth L J 2019 Statistical Process Control Charts for Monitoring Staphyloccocus aureus Bloodstream Infections in Australian Health Care Facilities Quality Management in Health Care 28 pp.39-44