Design and implementation of a data-driven tobacco production line warning system

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Abstract. In various stages of cigarette production, abnormal data is often generated, directly or indirectly impacting product quality and output. Previous studies relied on tobacco warning systems to monitor and alert on data exceeding set thresholds, reducing production losses caused by abnormal data. However, these methods didn't delve into the correlation between tobacco production data and equipment parameters. To address this, our paper introduces an optimized method for the tobacco production line warning system based on feature analysis. This approach establishes a link between process parameters and equipment characteristics, explores their correlation through data analysis models, and selects the best warning parameters by comparing model accuracy. Experimental results indicate that our proposed method significantly enhances the accuracy of the warning system compared to traditional tobacco warning systems.

Keywords: Quality warning, PLC, Cigarette manufacturing

1 INTRODUCTION

With the integration of industrialization and informatization, technologies like the Internet of Things (IoT) and artificial intelligence (AI) are extensively employed in industrial manufacturing[1]. This integration paves the way for innovation in the tobacco production industry. In the practical production of tobacco, there exists a delay and irreversibility in the feedback of quality indicators from key process sections in the workshop. This delay results in unresolved quality issues, impacting the stability of production process quality and, consequently, affecting product quality[2]. Prior solutions have predominantly relied on early warning systems to promptly alert anomalies in the production process and prevent production losses[3].

In the tobacco production process, the application of warning systems has become a common practice in the industry, but existing tobacco warning methods lack further utilization of warning data[4-5]. For example, the current new tobacco production system is based on MES data collection and processing systems, which cannot conduct real-time analysis and early warning of process indicators, resulting in delayed operation intervention and equipment maintenance, which can easily lead to uneven water addition and directly affect product quality.

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To enhance the early warning system's accuracy, we present an implementation method for a data-driven tobacco production line warning system, this approach investigates correlations between equipment characteristics and process parameters, transforming critical quality factors into identifiable production data. It employs real-time monitoring of process feedback indicators, analyzes their characteristics, establishes set values for various parameters during high-quality tobacco production, and builds a data model. Through iterative testing to refine accuracy, the system issues warnings for parameters exceeding quality indicators or displaying deterioration. Simultaneously remind operators to perform manual intervention to achieve early warning of product quality.

This article is divided into five chapters. Chapter 1 introduces the background of raising the problem and the methods of solving the problem; Chapter 2 introduces the research status of the researchers; Chapter 3 introduces the workflow of this method. Chapter 4 demonstrated the effectiveness of the proposed method through experiments; Chapter 5 provides a summary of the entire work.

2 RELATED WORK

O'BRIEN S P[6] uses FASE in statistics to analyze the relationship between macro structural factors of a country and major historical events, which can accurately predict the instability rate of a country within 5 years and also accurately predict its intensity level.

Guzzetti F et al.[7] studied landslide warning systems in 13 regions worldwide from 1977 to 2019. Due to significant differences in environment and climate across different regions, such early warning system models are not universal.

Yin[3] has developed a real-time monitoring and early warning system for the main transmission torque of the YF17 cigarette conveying and storage device. This device is beneficial for reducing quality faults in the cigarette manufacturing process, but it cannot achieve early warning of the entire cigarette quality index.

Zhang[8] conducted research on the supervision and early warning of the tobacco retail market in a certain city, and made good plans for the cigarette sales process, providing good early warning thinking for production and manufacturing enterprises.

Zhao[9] has developed and applied a comprehensive warning system for cigarette business objectives. This method facilitates management personnel to grasp real-time abnormal information in various business processes.

In summary, the early warning awareness of the cigarette industry is very avant-garde, and it has made many contributions in business, logistics, and other aspects through the use of big data information technology. However, it has been applied less in cigarette production enterprises, with more macro ideas proposed. There is little research on the specific implementation of quality and process indicator early warning.

3 DESIGN AND IMPLEMENTATION OF A DATA-DRIVEN TOBACCO PRODUCTION LINE WARNING SYSTEM

3.1 System operation process

The architecture of a data-driven tobacco production line early warning system model revolves around communication design, data collection, data processing, algorithm model construction, and the implementation of early warning system functions. Figure 1 shows the workflow of the quality warning system.

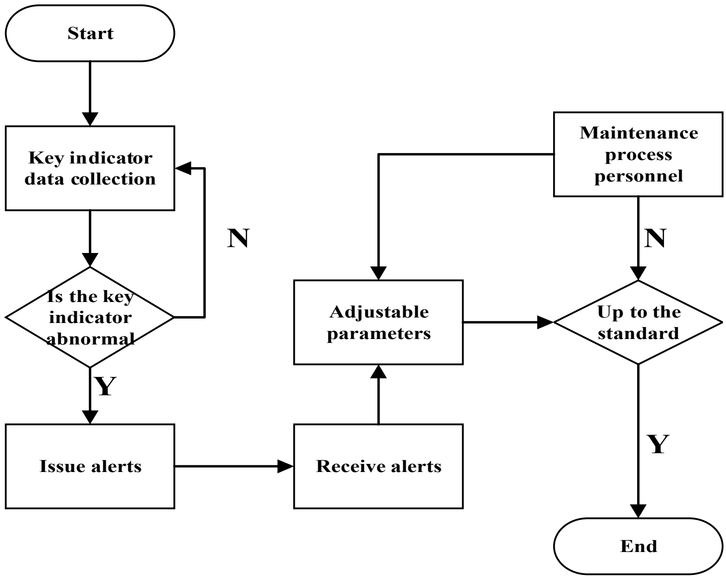

Fig. 1. The workflow of the quality warning system

3.2 Communication design

The core of the quality warning system is data-driven quality warning analysis. The analysis data is mainly composed of real-time production indicator data in the workshop, including various sensor data in the wire making process, frequency converter data, and control parameters and operating status data of PLC stations. The basic work of transforming communication into an early warning system in the original system is to analyze the IFIX server and database, confirm the OPC server used, and through data testing, confirm the success rate and data transmission ability of communication connectivity.

3.3 Production process data collection and processing

IFIX developed by General Electric (now part of Emerson), is a human-machine interface (HMI) and monitoring software. It offers a visual interface for industrial automation, allowing operators to monitor, control, and optimize processes. Additionally, iFIX facilitates historical data analysis, aiding in predicting issues, troubleshooting, and optimizing system operation.

The IFIX data management server consists of two main functions: (1) Real-time data collection: The IFIX warning client, through the IGS drive IO table, establishes a correlation between system I/O variables and field device data, and periodically collects device operating data, achieving communication between upper and lower data levels. (2) Data storage: The field device data (real-time data) collected by the IGS data acquisition driver is stored in a historical database. The historical database records device operating parameters and historical data. The warning process is shown in Figure 2.

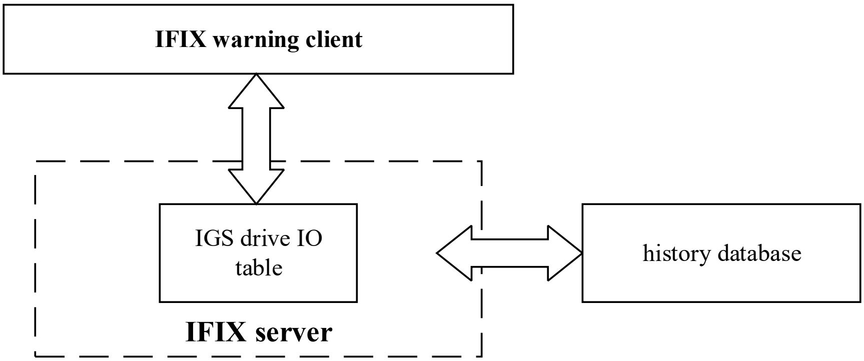

Fig. 2. Warning data processing

The actual production data is transmitted to the PLC or on-site workstation through hardware equipment in the production process, such as loose moisture regain, drying machine, feeding machine, etc., and stored in the industrial real-time database. The on-site workstation is then connected to the upper monitoring computer through IGS data drive, and configured for monitoring through the DCS control system client[10], Compare and analyze the collected data with the data in the standard database. If there are any abnormalities, proceed to the next step. If there are no abnormalities, cycle through the testing of new data.

3.4 Quality warning algorithm

In the early warning model, the larger the value of the process capability index(Cpk), the smaller the tolerance range of the product's dispersion relative to the technical standard, resulting in higher process capability.

The calculation formula for process capability index is shown in the following figure:

$$Cpk = Cp\left(1 - \left|Ca\right|\right) \tag{1}$$

In the formula, Cp represents process precision, and Ca represents process accuracy. The calculation formulas for Cp and Ca are as follows:

$$Cp = \frac{T}{6\delta} \tag{2}$$

$$Ca = \frac{\overline{X} - C}{T/2} \tag{3}$$

In the formula, T represents the specification tolerance $T = USL - LSL$, which is the upper limit minus the lower limit of the specification. $\overline{X}$ is the average value of the data, C is the median specification, δ The formula for calculating the standard deviation of the data is as follows:

$$\delta = \sqrt{\frac{\left(x_1 - \overline{x}\right)^2 + \left(x_2 - \overline{x}\right)^2 + \cdots \left(x_n - \overline{x}\right)^2}{n-1}} \tag{4}$$

3.5 Overall system architecture

The system has 6 modules, including leaf silk warning, stem silk warning, leaf silk warning parameter setting, stem silk warning parameter setting, trend curve and data report. The system logic framework is shown in Figure 3.

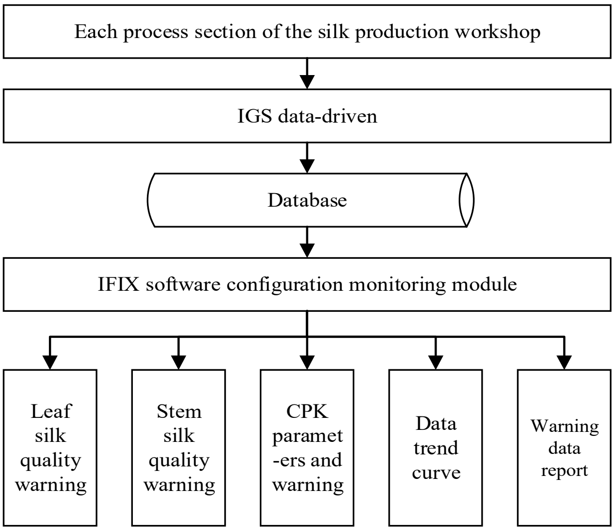

Fig. 3. Warning system logic framework

The early warning system combines data collection, data communication, data analysis and processing, and data display. Based on different grades and silk making equipment, it monitors the key production indicator data of the silk making workshop, tracks the changes in the core data CPK value in the silk making process flow in real time, and judges whether the process capability index meets the qualified rate of product production quality based on the fluctuation degree of CPK value. When the CPK value is below the set threshold range, the system triggers an alert task and displays an alert status prompt bar next to the abnormal data in the IFIX process interface, reminding technical personnel of abnormal points in the silk production process.

4 EXPERIMENTAL RESULTS AND DATA ANALYSIS

The data-driven tobacco production line early warning system proposed in this article can effectively establish a connection between production data and equipment parameter settings. Through real-time data obtained during production, instantaneous values are used to process alarms in the production indicator early warning system. When the collected data is within the alarm threshold range, the system will not alarm. When the collected data exceeds this threshold range, the system's key parameter indicators are abnormal, triggering the alarm system to issue an alarm.

Taking the hot air temperature in tobacco processing and production as an example, Tables 1 show the normal data, warning data, and alarm data of hot air temperature in the production lines for 2022 and 2023.

Table 1. Various data of moisture regain machine hot air temperature in 2022 and 2023.

Batch	Normal data proportion(%)		Warning data proportion(%)		Alarm data proportion(%)	
	2022	2023	2022	2023	2022	2023
1	66.0156	76.0314	23.8281	11.7878	10.1563	12.1807
2	79.0419	99.0234	5.0898	0	15.8683	0.9766
3	99.8081	99.8047	0	0	0.1919	0.1953
4	99.8088	99.8035	0	0	0.1912	0.1965
5	97.6608	99.8035	1.7544	0	0.5848	0.1965
6	89.3536	99.8043	10.4563	0	0.1901	0.1957
7	75.8491	96.8872	18.1132	1.1673	6.2264	1.9455
8	77.7164	99.8035	8.4715	0	13.8122	0.1965
9	94.8571	99.8047	4.9524	0	0.1905	0.1953
10	81.0345	99.8058	6.1303	0	12.8352	0.1942
11	53.9924	99.8039	13.308	0	32.6996	0.1961
12	83.9015	95.3347	15.9091	2.4341	0.1894	2.2312
13	93.3586	99.8039	3.2258	0	3.4156	0.1961
14	99.8095	99.8047	0	0	0.1905	0.1953
15	99.4329	86.7257	0	13.2743	0.5671	0.2212
16	86.6667	99.8043	5.1429	0	8.1905	0.1957
17	96.9582	87.5486	2.8517	4.2802	0.1901	8.1712
18	77.7567	97.8431	8.7452	1.9608	13.4981	0.1961
19	54.649	99.2248	14.0417	0.5814	32.0683	0.1938
20	73.4345	99.8058	14.0417	0	12.5237	0.1942

The data for 2023 was obtained using the method proposed in this article, it can be seen from the table that the alarm data for 2023 is significantly lower than that for 2022.

5 CONCLUSIONS

This article proposes a product quality early warning system based on the DCS control system and big data algorithm model, featuring real-time monitoring, quality warning, data trend analysis, and report display for key process equipment in the silk making workshop. Through big data analysis, the aim is to reduce defects and enhance production process optimization. The system utilizes Gaussian distribution intervals for early warning and introduces a threshold to determine the number of variables. It isolates fault variables below the threshold and issues a quality warning otherwise. In summary, the system relies on missing sensitive indicator values, real-time process monitoring, achieving comprehensive product quality diagnosis and warning. Its application in the tobacco industry is innovative, improving production controllability and optimization.

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