Fault monitoring of inner frame paper cutting transmission coupling of packaging machine based on intelligent analysis of noise

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Abstract. This article analyzes the noise signal of the packaging machine coupling through artificial intelligence technology, performs feature extraction and analysis on it, and realizes the status recognition and health analysis of the device. This method can successfully analyze the machinery and equipment to find the manual inspection. The problem that is neglected, the method of monitoring packaging equipment through noise energy is a new method with great potential for the actual plant environment.

1. Introduction
Packaging machine is an important equipment for high speed production line of hard pack. This equipment has a high degree of automation and advanced technology, but is affected by factors such as auxiliary materials change and reduced equipment coordination accuracy. In the long-term production process, small packets of aluminum paper are occasionally missing, skewed, spread, wrinkled and inner frames. Defective cigarette packs with missing or damaged paper. Since the original inspection on the equipment cannot effectively identify such defective products, it brings many inconveniences to the quality control of the operator. Defects in aluminum paper and inner frame paper are sporadic, unpredictable and uncontrollable. Only relying on the operator to watch for the inner frame paper falling phenomenon in the fourth round, or to perform high-frequency product self-inspection to achieve the quality control of aluminum paper and inner frame paper defects, not only wasting a lot of manpower, Material resources, but also cannot completely prevent the defective cigarette packets from entering the downstream unit or eventually entering the market.

The core equipment of the tobacco industry is highly automated and expensive. At the same time, the equipment has a large number of components and complex operating conditions. Common monitoring methods are difficult to achieve, and maintenance costs remain high [1-2]. In this regard, many scholars have carried out research on fault diagnosis and prediction, and evaluated the operating status and health level of equipment by collecting various signals during the operation of mechanical equipment. Generally, the state detection is performed by measuring performance parameters such as vibration, temperature, flow rate, and pressure, and the causes of failures are discovered by senior domain experts to perform fault diagnosis and prevention [3]. However, the labor cost for such a fault diagnosis is too high, it is difficult to guarantee 24 hours of uninterrupted operation, and the historical diagnostic data cannot be effectively used, and the diagnosis efficiency is low. By establishing a fault analysis model and a fault database, collecting and efficiently analyzing signals to realize automatic monitoring and fault diagnosis of equipment, these shortcomings of manual fault diagnosis can be effectively compensated.
Sound is the product of most mechanical equipment processing. It contains rich and characteristic information during the operation of the equipment. Its advantages in the following aspects make it very suitable as a starting point for diagnostic analysis. First of all, the diffractive nature of sound allows sound detection to penetrate deep into the device, and the sound of friction, shearing and other movements of the device has its distinctive characteristics, which can reflect the feature information of the device's movements and related components, making it easy to detect early failures [4]. Second, the sound collector is non-contact installed, which not only reduces the large energy loss of information transmission between different media [5], but also avoids interference with equipment work, which meets the needs of industrial data analysis; third, sound The testing technology has been extensively studied in the industrial field, and the relevant data analysis technology is quite mature [6]. It can be seen that the use of sound signals to analyze the status of mechanical equipment has unique advantages. In recent years, fault diagnosis technology based on sound signals has become a research hotspot. However, because the factory environment is quite complicated, the sound of a device is often disturbed by the noise of surrounding equipment, and the fault characteristic signal may be submerged in the background noise. Moreover, due to the continuous complexity and centralized development of the equipment, the signal has non-linear characteristics, multiple frequency components are superimposed, and even continuous spectral distribution appears [7]. Therefore, it is particularly important for the feature extraction of the original signal, which is also the difficulty of the research [8]. This paper collects and analyzes the noise signal of the frame paper cutting transmission coupling in the packaging machine, performs feature extraction and analysis on it to realize the status recognition and health analysis of the device.

2. Seq2Seq method of RNN

2.1. Data sources
In this study, the noise of the inner frame paper cutting part on the production line of a cigarette manufacturing company was used for research. The application site map is shown in Figure 1. The red circle marks the installation position of the microphone for recording noise. The noise data is transmitted wirelessly. The network is transmitted to the cloud server for invocation [9]. Because the original signal sampling rate is 48000Hz, the direct traffic cost is too high. In this study, the feature extraction of all sound signals was performed on a small processor at the microphone end, and the 24Hz feature signal was transmitted back to the server. The noise source recorded by the microphone is mainly the transmission coupling of the inner frame paper cutting part, and is doped with noise and background noise from the remaining parts nearby. This research will analyze the noise to realize the working condition monitoring and fault diagnosis of the inner frame paper cutting parts.

![Figure 1. Application scenario example.](image)
2.2. Hardware
Data collector: Collect noise in the environment in real time, extract sound characteristics that reflect the operating status of the machine and equipment from the noise, and send it to the cloud server. Because the noise is transmitted through the air, the box does not need any mechanical connection with the monitored equipment, which is extremely convenient to deploy and has minimal impact on production.

Server—a private server placed at the client or a cloud server deployed in the cloud, used to store, manage, and analyze noise characteristic data, and display the health status of the device in real-time in the form required by the client through a web page.

2.3. Software part
Noise feature set—we have specifically defined a set of feature sets for the physical characteristics of machine noise. This feature set contains multiple physical quantities such as time, frequency, and energy, as well as linear or non-linear combinations of some physical quantities. The machine noise is optimized, which is very different from the widely used voice features, which can effectively improve the recognition accuracy. At the same time, this feature set covers the noise characteristics of typical damage such as wear, looseness, fatigue, cracks, etc., which is extremely beneficial for achieving predictive maintenance.

Big machine noise data—with the assistance of operators, the system learns to establish the correspondence between the operating status and acoustic characteristics of various equipment in the plant to form a big noise data system. During actual operation, the system will collect the sound in the plant, identify and judge it, and report the operation and damage status of each equipment in real time. If unknown features are found, the system will give a reminder or alert. Operators can define this unknown feature and join a big data system based on the actual situation. When this feature is encountered again in the future, the system can directly report the new status according to the definition.

System display interface—Customers can check the running status and health of the machine and equipment in real time through the computer or mobile phone, and can choose the time period of interest to statistics the production and understand the overall operation of the production line or factory in real time.

2.4. Research methods
Spectrum analysis is one of the common signal processing methods in equipment fault diagnosis applications. The occurrence and development of faults often cause changes in the signal frequency structure. The purpose of this study is to diagnose equipment failure. The monitoring program only needs to analyze the noise in the running state. Therefore, it is necessary to first realize the detection of the equipment state and automatically distinguish the running and shutdown states of the equipment.

In the scenario of equipment health management, there are not many impacted results, such as auxiliary materials change and equipment components. This article attempts to use the Seq2Seq model for multivariate sequence estimation.

Seq2Seq is an Encoder–Decoder network. It handles the task of sequence-to-sequence mapping. Encoder maps the input sequence encoding to semantic space and turns it into a fixed-length vector expression. Decoder decodes this semantic vector. A signal sequence that becomes a variable-length target. After the attention mechanism is introduced, the output network will automatically learn the weight of its corresponding input relationship. The most flexible part of the Seq2Seq structure is that the length of the input sequence and the output sequence are variable, which can be used for translation, chatbots, syntax analysis, text summaries, etc., and also suitable for sequence estimation scenarios.

In this article, we take the data at k time points as input, and then the data at m time points as output. This window of length k + m can slide to build batches of samples. The structure of Encoder and Decoder uses LSTM model of RNN.
The training process is shown in Figure 2.

![Figure 2. Seq2Seq main graph.](image1)

Take the spectrum as input and health as output for training. Feature extraction as shown in Figure 3.

![Figure 3. Feature extraction.](image2)
3. Application effects
During the normal operation of the frame paper cutting part in the packaging machine, the stability and health usually show a score of 95 or more, and the trend health fluctuates between 75 and 100. However, after monitoring for a period of time, the sudden decline is seen from the stability health curve.

It was confirmed on site inspection that the decline of this health curve corresponds to the damage of the inner frame paper cutting part coupling. After a period of maintenance, the assembly line returned to normal operation and health improved. But after more than a month, the stability and health curve showed signs of decline again, only slightly. That reflects that the part still has problems. Subsequent comprehensive and in-depth inspections of the components found that there were unfastened bolts inside the components. After completely repairing them, the health curve returned to normal levels again. It can be seen from this case that relying on noise energy to monitor the running health of components can detect equipment failures in a timely manner, and this method also has better sensitivity to subtle problems inside the equipment, which is a reliable means for equipment failure monitoring.

4. Conclusion
In this study, a microphone was used to record the operating noise of the inner frame paper cutting component in the assembly line of a cigarette manufacturing enterprise. The monitoring of the noise energy and the evaluation of the component's health index realized the timely diagnosis of component failure in actual cases. And the method is sensitive to the details, and accurately found the missing bolt problems during the repair process. It successfully analyzed and found the problems ignored by manual inspection, eliminated the hidden dangers of the subsequent operation of the equipment, and proved its effectiveness in the tobacco industry fault diagnosis. Because relying on noise for diagnosis has the advantages of convenient deployment and easy universality in different scenarios, this method is expected to become an excellent method for fault diagnosis of tobacco equipment.

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