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Application of Digital Signal Processing Technology in Fault Detection

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Abstract:

This paper elaborates on the characteristics of digital signal processing technology and its application in fault detection, including the overall design of the diagnostic scheme, the design of diagnostic methods, and incremental clustering algorithm diagnosis. The aim is to improve diagnostic speed and accuracy and reduce the risk of faults.

Keywords:

Digital signal processing
Incremental clustering algorithm
Fault detection

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1. Introduction

The high level of automation in modern industrial systems leads to complex structures, and when a subtle stage within the system malfunctions, it not only may cause a series of adverse reactions but also has the potential to affect the optimal operation of the system.

2. Research background

The characteristics of Digital Signal Processing Technology are as follows.

(1) Technical features: Currently, signal processing systems are often separated from Personal Computer (PC) based embedded systems. Although PCs are functionally complete and convenient to use, they are limited to specific requirements for signal analysis and still face difficulties in their application. Real-time signal analysis systems offer low latency and low cost. For signal analysis, simulation software (such as Matlab or C++) is commonly used on general-purpose computers, suitable for non-real-time digital image processing technology systems. When high computational speed is required, dedicated digital image processing chips can be considered. Signal processing algorithms can be obtained directly from these chips, requiring only interface design without additional programming. Although upgrading both hardware and software in this type of system can be challenging, its excellent performance in signal analysis still offers significant application prospects and practical value.

(2) Digital signal processing chip: The digital signal processing chip is a data signal converter constructed using processing algorithms. It

consists of a Central Processing Unit (CPU), memory, and integrated external devices, containing various processing and control modules. Overall, digital signal processing chips exhibit very high processing speeds. The CPU maintains excellent computational speed, and multiple external interfaces allow for the separation of program instructions and data storage, enabling simultaneous processing and data analysis. The commonly used pipeline structure ensures fast response times, while the chip interface supports real-time debugging and stable development and design performance [1-3]. As the capabilities of digital image processing technology continue to improve, the use of dedicated components for real-time digital image processing has become a major development and design focus. Each storage space in digital image processing technology can be independently accessed, and the program flow bus and data bus are separated, doubling data computation efficiency. Data and program flows are located in different storage spaces, enabling the overlap of execution controls, enhancing chip flexibility, and facilitating the execution of instructions. Despite the high demands on practicality in digital image processing, functional programs can leverage integration advantages through predictive methods in different scenarios. These chips also possess features not found in other processors, such as performing multiplication and addition calculations within an instruction cycle, along with simultaneous instruction fetching and data statistical analysis.

3. Digital signal processing technology

At this stage, digital technology is booming. With the advancement of science and technology, professional technologies related to digitization have been able to develop better, and upgrades have become more rapid. In this context, the advantages of the digital era have gradually emerged, especially the promotion and popularization of digital image processing technology, which has made substantial progress [4]. This indicates that digital signal technology has become a major force in social development. Currently, digital signals have slowly penetrated various industries and are widely used, whether in communications, the internet, or mechanical equipment, and they play an important role in providing brand-new upgrade opportunities for scientific and technological innovation. Digital signal processing mainly involves converting commonly used video templates and material images in life into analog signals and completing the work of receiving and uploading based on these digital signals. To achieve the function of transmitting information, digital signal processing needs to rely on computers or processing chips. Digital signal processing has strong applicability, and its research, development, and popularization have positive significance.

4. Application of digital signal processing technology in fault detection

4.1. The overall design of the diagnostic scheme is carried out

Currently, improved diagnostic methods in industrial systems can effectively ensure the safety and stability of system operation. In contrast, ineffective fault diagnosis methods may directly impact the system's operating status. In designing the diagnostic approach, cluster analysis can be used to integrate unlabeled big data into distinct categories through computation, allowing for identification and understanding of the hidden data groupings and information distribution within the dataset [5]. A clustering algorithm based on density index value rules treats all data objects as potential targets for fast and individualized clustering, with a linear relationship between computation volume and the number of data points.

4.2. Design of diagnostic methods

Among the existing fault detection technologies, given the complexity of some algorithms and the large amount of data to be processed, coupled with the high demand for real-time performance in multiplication operations, the application of digital signal processing technology can provide us with a very effective solution to construct a system program that plays a role in monitoring and fault diagnosis in complex environments.

(1) The main approach used in the development of digital signal processing programs is to download complex computation processes as programming code to hardware systems using C language and other measures. After understanding the computational rules, optimization algorithm functions can be written and adjusted based on simulation results. If the expected optimization algorithm can be completed, the digital image processing programming environment can be used to perform transformations on the knowledge program. If the expected optimization algorithm is not completed, the program can be written again. After this step is finished, simulation software is needed to adjust the function of the optimization algorithm program flow, and then the processing results of the expected algorithm are compared with the actual results to make the online operation quality and characteristics more durable.

(2) Excellent results were achieved in diagnosis by relying on the optimization algorithm transplantation method of Matlab simulation. The overall software part of digital image processing also uses modular programming design. The specific needs of fault detection are met by sequentially calling different functional modules in the main function. The detection system first resets, and after the reset is complete, it gradually acquires data and places all the data information in a buffer area for subsequent processing. The system automatically transfers the noise-processed data information to the fault detection clustering analysis control module and also stores the information and determines whether there is new information. When new information is stored, noise reduction preprocessing is performed. It should be noted that the effect of wavelet denoising is to preserve useful signal technology before combining and reconstructing data signals. Overall, the specific process of the clustering algorithm function module can perform clustering algorithms within dedicated threshold ranges, and finally store the results by adjusting the clustering centers through calculations.

(3) If the inspection method needs improvement, an enhanced assembly language should be used for programming, and the program optimization process will require manual intervention. That is, the calculation method is first optimized at the C program flow level. Then the coding is adjusted according to the specific characteristics of digital image processing, mainly including function simplification, algorithm design loop improvement, and coding parallel computing. However, it is necessary to try to prevent the loading and enabling of data stored outside the chip, as the goal is to reduce the time consumption caused by enabling data information.

4.3. Diagnostic approach using incremental clustering algorithms

Nowadays, common clustering methods are based on global comparisons, which cannot meet the demands of statistical data analysis in clustering algorithms according to real-world standards. For newly added information, the application of incremental clustering algorithms can be considered for diagnosis [6]. This involves first identifying the optimal data object set and original clustering centers using a subtractive clustering algorithm strategy, and then conducting further analysis. This approach not only avoids the difficulty of finding the optimal solution in every clustering calculation but also determines the number of clusters based on data points in the data target. Conversely, recursive incremental clustering uses the original clustering results instead of the entire dataset for re-operation. In this case, emphasis is placed on improving the efficiency of the clustering algorithm to ensure the accuracy of data processing.

5. Conclusion

The scientific research of digital signal processing technology has become the core of future condition assessment and fault testing. It aims to improve diagnostic speed and accuracy, reduce false alarms and missed reports, analyze and determine fault states, and assess their risks. Future industrial systems will be more complex, and in the context of integration, relying solely on optimizing algorithms for noise processing is undoubtedly insufficient. Predictive analysis and upgrades are also anticipated to improve the fault detection process, enhancing the algorithm's ability to process and respond to high-dimensional data, especially in fault correction and control.

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Disclosure statement

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