Application Research of Mathematical Morphology in Signal Processing

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Abstract: The application of mathematical morphology in image processing has been extensive, and with the deep research on mathematical morphology theory, its application development in signal processing is receiving more and more attention. As a nonlinear signal processing method, it extracts the features of the signal completely in the time domain. Compared with some other non-stationary and nonlinear signal processing methods, it has many advantages such as amplitude non-offset and phase non-attenuation. Therefore, this method has been applied to signal processing in various industries. However, the system's summary of the application of this technology in signal processing and research is still rare. It mainly expounds the basic theory of mathematical morphology, summarizes the application of mathematical morphology in power system, mechanical fault diagnosis, medical signal processing and speech signal processing. Finally, it summarizes the application prospect of mathematical morphology in signal processing and puts forward a number of issues that need to be addressed.

1. Introduction

The traditional Fourier transform method is usually used to analyze the signal. The Fourier transform is a mathematical tool for transforming the time domain and the frequency domain. In essence, the essence is to decompose the signal into a superposition of sine waves of many different frequencies. In this way we can turn the study of the waveform function into a study of its transformation. When noise is mixed in the signal, the usual method is to transform the noise-mixed signal into the frequency domain. According to the frequency band occupied by the wanted signal and noise in the frequency domain, pass the low-pass, high-pass, band-pass or band-stop filter. The noise is filtered out, and then the signal is reconstructed to restore the original signal, but the actual noise and useful signals are usually inseparable in the frequency domain, such as random noise, white noise, and the like [1].

In order to solve this problem, people are always looking for new methods. In recent years, mathematical morphology based on the visual characteristics of images or signals has been widely used in the field of image processing. It rejects the traditional numerical modeling and analysis perspectives and depicts and analyzes images from a collection perspective. The basic idea of studying image geometry is to use a structural element to detect an image to see if it can be well placed inside the image and to verify that the method of filling the structural elements is valid. Therefore, the performance of morphological operators will be characterized primarily in a geometric manner. This explicit geometric description is more suiTable for the processing and analysis of visual information.

In the field of signal processing, as a powerful application software, its Fourier analysis toolbox and wavelet analysis toolbox have been very mature, and researchers can apply the function functions provided by them to the actual work, but the morphological toolbox currently It also focuses on two-dimensional image processing, and does not provide a corresponding function in one-dimensional signal processing. In view of the impressive achievements of mathematical morphology in image processing, the development of its one-dimensional signal processing toolbox for researchers better applications are valuable.

This paper is based on the in-depth study of the basic theory of mathematical morphology, and writes its one-dimensional signal shape processing function, including corrosion, expansion, opening, closing and other morphological operations, and applying these basic functions to the

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one-dimensional signal. The noise filtering characteristics are simulated and analyzed to deepen the understanding of the relevant characteristics of the method. The structural elements are a very important concept in mathematical morphology. In this paper, the effects of the shape, length and amplitude on the filtering effect are investigated. In the latter part of the paper, wavelet and morphological filtering methods are applied to filter the sinusoidal and Doppler signals mixed with random noise. The simulation results show that the morphological filtering method is better than the wavelet transform method for high and single-frequency noise-added signals [2].

2. The Research Content of Mathematical Morphology

Originally, mathematical morphology was based on set theory. It was a set transformation with certain constraints, called continuous morphology, and later developed into discrete morphology based on discrete point sets. From the perspective of the research object, morphology has also expanded from the earliest binary morphology to gray value morphology. Especially in the past ten years, the penetration and fusion of mathematical morphology with other related disciplines has led to many branches, such as the injection of sorting statistics, which has made the development of mathematical morphology into a sequential morphology, which is mainly studied. It is a discrete multi-valued signal image whose main operation is a local sorting statistical operation. The combination of fuzzy logic and mathematical morphology has emerged into fuzzy morphology, which introduces fuzzy sets into morphological operations, thus forming fuzzy morphological transformations for processing image signals. In addition, morphological and neural networks merge with each other to form another development direction, a morphological neural network, which is a special case of artificial neural network development, but it has obvious differences compared with neural networks. The main difference lies in the network. The algebraic combination of the numerical information connection of neuron nodes is different. In the classical neural network, the information combination of each node is multiplied by the respective response values of the nodes and the weights are added, and then the results are added together in the morphological neural network. In the middle, the information combination of nodes is completed by adding and taking extreme values. Because of this difference, morphological neural networks will have special applications, and it is expected to gain important applications in the fields of image processing, nonlinear pattern recognition and artificial intelligence. Soft mathematical morphology is also an important branch of mathematical morphology development. This method replaces the minimum and maximum methods with sorting weighted statistical methods. The structural elements are composed of two parts, the core and the soft boundary, which have stronger anti-noise ability. Additive noise and small shape transformations are not sensitive. Recently, the proposed shape wavelet is a nonlinear multi-resolution analysis method, which takes into account the advantages of mathematical morphology and wavelet transform, has better multi-resolution analysis characteristics and better anti-noise performance. Nowadays, mathematical morphology has become an important aspect of image processing theory. It is widely used in various fields of image processing. Mathematical morphology can be used for image enhancement, segmentation, edge detection, morphology analysis, image compression, etc. Various treatments. After decades of development, the theory and application of mathematical morphology have achieved remarkable achievements [3].

3. The Application of Mathematical Morphology in Signal Processing

Mathematical morphology was first applied in the field of image processing. In recent years, mathematical morphology has been gradually introduced into the field of one-dimensional signal processing, and some gratifying results have been achieved. At present, the application of mathematical morphological methods in signal processing mainly focuses on the following aspects:

The Application of Mathematical Morphology in Electric Power System. In the power system, in order to ensure the safety of the power equipment and to ensure the transmission of high-quality power, how to properly process the information obtained from the system at a timely time becomes a very critical issue. At present, the signal processing methods in the power system mainly include Fourier transform FT, short-time Fourier transform SFT, wavelet Transform WT and so on. However, these methods have certain limitations, such as the obvious lack of filtering effect of impulse noise, so people began to find a better way to filter out positive and negative pulse noise. The shape-based filter based on mathematical morphology has excellent performance in filtering positive and negative pulse noise, so it has attracted the attention of the industry.

From the current research field, it can be seen that the application of mathematical morphology in power systems mainly focuses on transient signal harmonic analysis, power quality detection, fault diagnosis and positioning, relay protection and fault location. The literature proposes a multi-resolution morphological gradient method to extract transient characteristics in the power transmission line signal and to accurately determine the fault. In the literature, the effects of the shape, amplitude and width of the structural elements on the performance of the morphological digital filter are studied by numerical simulations for various interferences in the monitoring of power signals. According to the special electrical structure and fault diagnosis requirements of railway power lines, the paper proposes the voltage traveling wave signals generated when the faults are collected from both ends of the line, filtering with mathematical morphology filters, and using morphological gradient techniques to find the singular value points of the waveforms. And then use the improved double-ended positioning formula to calculate, in order to get a new method of the precise segment of the fault. The literature systematically introduces the application of mathematical morphology theory in relay protection of electrical systems. Two morphological algorithms suiTable for power system transient signal analysis, namely morphological signal decomposition and multi-resolution morphological gradients, are successfully summarized and applied to the identification of excitation inrush current and ultra-high speed transient protection in transformer protection. Fault transient waveform feature extraction. [4]

Mathematical morphometry mainly uses such methods as the signal analysis of the power system: after the waveform transforms the sudden characteristics of the signal, the signal is denoised and filtered, the waveform of the signal is decomposed, and the shape of the waveform is analyzed. At present, the morphological theory used in the electric system is mainly the shape filtering, the gradient operation, etc. How to apply some new morphological theory to the power system, such as the morphological operation and the flexible morphological operation, is still a difficult point of research. With the deepening of the theory and application of morphology, mathematical morphology is bound to be more widely used in power systems.

The Application of Mathematical Morphology in the Processing of Voice Signals. Speech signal processing is a cross-disciplinary subject with a wide range of topics and is one of the core technologies in the field of communication. In speech signal processing, the removal of noise signals has always been an important part of speech signal processing, but since speech signals are a complex nonlinear, non-stationary signal, some traditional linear and stationary signal processing methods have Great limitations. In recent years, some non-linear non-stationary signal processing methods have been gradually introduced into the speech signal processing, which has made up for some shortcomings of the traditional linear processing method.

A shape filter based on mathematical morphology is a new type of nonlinear filter. Because of its good filtering performance, it can effectively suppress various noises in speech signal processing, and it is beneficial to maintain the details of speech signal edges. In recent years, people have begun to explore its application in speech signal processing. Based on the mathematical shape filtering method, the literature proposes two schemes for extracting the pitch period of the speech signal in the time domain and the frequency domain. The spectral envelope of the speech signal can be extracted while extracting the pitch period in the frequency domain. This new approach is simple, intuitive, and computationally efficient, suiTable for parallel processing and easy to implement. The experimental results show that the selection of reasonable mathematical shape filtering parameters and linear prediction coding parameters can obtain accurate speech signal accent features. For the one-dimensional speech signal, the literature proposes a speech-based enhancement method based on morphology. Through performance analysis and comparison, it can be seen that the method effectively suppresses the interference of noise, and the quality after speech enhancement is obviously improved. Since the performance of the shape filter is related to the selected structural elements, and the width of the structural element has a large influence on the output signal-to-noise ratio of the enhanced speech; the corresponding structural elements should be selected according to the characteristics of the different speech signals.

In short, the mathematical processing method based on mathematical morphology is still in the trial stage. There are still many problems that need to be solved, and more new methods are needed. For example, how to use the white adaptation method to best estimate the selection of structural elements remains to be further studied. The application of mathematical morphology in the processing of speech signals becomes an important branch of the non-linear processing method of speech signals [5].

Application of Mathematical Morphology in the Processing of Medical Signals. In the medical field, the heart sound has an extremely important clinical value, so the detection and analysis of the heart signal is very important. It is an important day for understanding the heart and blood vessels. During the acquisition of heart sound signals, the introduction of noise signals is unavoidable due to factors such as environmental conditions and other equipment. To accurately identify the heart sound component, you first need to denoise the collected heart sample signal. For the wavelet filtering algorithm which has been widely used in the field of signal processing, it has a good processing effect when dealing with high-frequency interference signals, but it will cause distortion of low-frequency components when filtering low-frequency interference signals: The morphological filtering algorithm has a good effect on filtering out low frequency interference signals. In the 1990s, the non-stationary and low-frequency characteristics of the heart sound have been used in the medical processing field in the field of mathematical processing. This method is used to extract the envelope of the heart signal, to remove the noise interference in the heart signal, and to obtain a clearer heart sound map, which lays a further foundation for the recognition of the heart sound and the analysis and diagnosis. The morphological filter is used to process the electroencephalogram signal, and the background signal is separated from the data containing the spike component to automatically interpret the recognition. The literature applies mathematical morphology to the study of the extraction and identification of the heart sound envelope. Firstly, the original heart sound is preprocessed by morphological filtering and full-wave rectification; then the morphological closed operation is used to extract the heart sound envelope; finally, the morphological opening operation is used to eliminate the noise envelope and accurately extract the characteristics of the heart sound signal for further Heart sound analysis and heart sound diagnosis laid the foundation.

Application of Mathematical Morphology in Vibration Signal Processing. In the field of mechanical equipment fault diagnosis, the analysis and processing of vibration signals has always been the focus and hotspot of research. Although traditional signal processing techniques have become more familiar in theory and practical applications, their scope of application is limited to flat and linear signals due to their limitations. In the mechanical equipment failure, the nonlinear non-stationary signal is often measured. Compared with the signal processing method of nonlinear non-stationary signals such as wavelet transform, short-time Fourier transform and wing distribution, mathematical morphology is used to deal with the signal processing method. The vibration signal can achieve better filtering effect, and it is fast, accurate and real-time. When using the mathematical morphology method to process the vibration signal, the morphological method should be introduced according to the characteristics of the vibration signal, and the mathematical shape filter is constructed to process the vibration signal with noise to eliminate the noise in the vibration signal, thereby extracting the signal. Features, reconstructing the original signal. The current application of mathematical morphology in the failure of mechanical equipment mainly focuses on some analysis of the vibration signals of gears and bearings, and has obtained some research results.

The literature applies mathematical morphology method to extract the envelope characteristics of vibration signals, and studies the morphological operations such as corrosion, expansion, opening and closing operations and the influence of structural elements on the analytical performance. The method is applied to extract the inner and outer rings of rolling bearings. Fault characteristics; the morphological filtering of the defect bearing vibration signal of the literary and literature parts of the manuscript is extracted, the pulse signal is extracted, demodulation is performed, and then the spectrum analysis of the demodulated signal is performed to identify the cause of the fault. The literature based on mathematical morphology of the rotating mechanical vibration signal processing method proposes a mathematical shape-based filtering method to deal with the rotating mechanical vibration signal collected in the field to eliminate noise pollution and DC deviation. In this paper, based on the mathematical shape filtering, the gear fault feature extraction method is applied to the extraction of gear fault features. A new method for morphological filtering of gear fault signals based on signal shape characteristics is proposed. The morphological filtering is used to suppress signal noise and preserve signal nonlinear characteristics. The role of the aspect. The results show that the shape filtering can be used to extract the impact fault features hidden in the noise from the gear breaking signal. When using the morphological method to analyze the vibration signal, the main problem to be solved is to select the appropriate morphological method, optimization filter design, and structural element design according to the characteristics of the vibration signal. The research on the shape filtering according to the mathematical morphology has only just begun in the research of the fault diagnosis vibration signal, and there are still many research contents to be explored. Due to the non-linear filtering characteristics of mathematical morphology and the multi-resolution characteristics of wavelet transform, the shape wavelet with better detail retention and better anti-noise performance will be the focus of future research. It can be foreseen that with the deepening of mathematical morphology research, the application of shape filtering in the diagnosis of equipment faults will be more and more.

4. Conclusion

The current mathematical morphological signal processing method has been applied in some fields although it has been successful today. However, there is still a preliminary understanding of the research and application of mathematical morphology signal processing methods. There is still a lot of room for development. With the development of mathematical morphology signal processing method theory and the emergence of some new signal processing methods, how can Applying them together in actual signal processing remains to be studied.

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