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Radar Signal Intelligent Detection Based on Wavelet Transforms

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ABSTRACT

Radar target detection is mainly to detect the target from noise, clutter and other clutter interference, and to extract the relevant information of the target. The security effectiveness of radar system is restricted, so how to improve the radar target detection performance is always the focus and difficulty of research. In recent years, the rapid development of fuzzy technology and its better adaptability to non-stationary environment have been widely used in control, communication and signal processing. Therefore, this paper mainly studies the radar if signal detection method based on fuzzy theory, and carries on the simulation verification to the algorithm. Concretely introduced the radar signal detection of the radar signal detection, creating the data analysis theories and the model system for the modern and radar signal detection method from the method, provide the theories frame of the data analysis.

INTRODUCTION

Radar Design is a text-reference designed for electrical engineering graduate students in colleges and universities as well as for corporate in-house training programs for radar design engineers, especially systems engineers and analysts who would like to gain hands-on, practical knowledge and skills in radar design fundamentals, advanced radar concepts, trade-offs for radar design and radar performance analysis. This book is a concise yet complete treatment of the relationship between mission-level requirements and specific hardware and software requirements and capabilities [1-3]. Although focusing on surface-based radars, the material is general enough to serve as a useful addition to books currently available for this purpose. It covers all phases of design and development, including the development of initial concepts and overall system requirements, system architecture, hardware and software subsystem requirements, detailed algorithms and system integration and test. A wealth of information is provided to rarely cover [4-7]. It is unique in that it provides a hands on and how to perspective on applying radar theory to design and analysis. Rather than being a theory and derivations-type, this book is applications-oriented making it different from other published works on this subject. All measures are referred to as radar signal processing and radar data processing that calculates from the received echo signal an evaluable image on the radar display [8-11]. With radar signal processing is referred the part that is still dealing with the analog (or often present even as a digital value) magnitude of the echo signal. The radar data processing is the part of processing, which concerns only the information about a target. In between, there is the process of measuring the coordinates of the reflecting object. In the era of analog radars, the possibility of radar signal processing was still very limited and consisted mostly of a system for suppressing interference only. The radar data processing consisted essentially only of the experience of the operator [12,14]. The operator must visually identify the target signals, which consisted in a tangle of spots on the screen, consisting of noise, fixed target and weather disturbances. Radiolocation was determined by the decision of the operator to draft a message about a blip on the screen. Then, the coordinates of the target character were measured by the operator. This could be done either by visually estimating the azimuth angle and the distance (in polar coordinates) or by assigning to a grid square (Cartesian coordinates). With the introduction of digital display systems now, however, the technology must perform this task. Fortunately, technological progress is already so far advanced that digital computerized procedures not reduce the performance of the radar in the field of signal processing. In various radar sets the logical functions of the radar signal processing, however, can be summed up in a few modules in practice [14-17]. Thus, the plot extractor may be united with the plot processor and the various plot combiners and all together can be combined to form a single assembly. The most complete, current guide to the signal processing techniques essential to advanced radar systems Fully updated and expanded, Fundamentals of Radar Signal Processing, Second Edition, offers comprehensive coverage of the basic digital signal processing techniques and technologies on which virtually all modern radar systems rely, including target and interference models, matched filtering, waveform design, Doppler processing, threshold detection, and measurement accuracy. The methods and interpretations of linear systems, filtering, sampling, and Fourier analysis are used throughout to provide a unified tutorial approach. End-of-chapter problems reinforce the material covered. Developed over many years of academic and professional education, this authoritative resource is ideal for graduate students as well as practicing engineers. Fundamentals of Radar Signal Processing, Second Edition, covers: Introduction to radar systems Signal models Pulsed radar data acquisition Radar waveforms Doppler processing Detection fundamentals Measurements and tracking Introduction to synthetic aperture imaging Introduction to beamforming and space-time adaptive processing [18-20]. Modern radar has been widely used in military and civil fields, but the radar system is faced with a very complex environment, which contains a lot of clutter, interference and internal noise in the radar echo, so it is of great significance to study the radar echo noise reduction technology. Wavelet analysis theory is a popular analysis tool, which has been developed rapidly in the field of signal processing. Modulus maxima method and threshold method are the most widely used wavelet denoising methods. Combining the characteristics of radar noise and the current research direction, this paper mainly discusses the threshold noise reduction algorithm and its improvement. In engineering applications, it is difficult for software method to achieve real-time noise reduction, so hardware method must be adopted. Due to the popularity of FPGA development method, the design of wavelet noise reduction module based on FPGA is proposed in this paper. The main work is as follows: first, the basic knowledge of wavelet theory is introduced systematically, the basic ideas of multi-resolution analysis and wavelet decomposition are expounded, and the implementation process of discrete small sweep algorithm is further discussed. Secondly, according to the characteristics of radar signal and noise, wavelet theory is applied to radar signal denoising. MATLAB is used to simulate the wavelet threshold noise reduction, and the results of different threshold processing methods are compared, which is suitable for radar signal noise reduction [21,22].

Wavelet transformation

Wavelet transformation is a time-frequency analysis method of signal. It has Multireslution Analysis' quality as well as has the ability of describe the signal's part character in both time and frequency range. It's a settled window width but protean form time-frequency analysis method, which has protean time window and frequency window. It has high frequency resolving power and low time resolving powering low frequency, high time resolving power and low frequency resolving power in high frequency. It accord to low frequency's laggard transformation and high frequency's fast transformation quality. Wavelet transformation is suitable for detecting the instant breakpoint in natural signal. Its definable form:

$$W_{f(a,b)} = |a|^{-1/2} \int_{-\infty}^{+\infty} f(t)\psi[(t-b)/a]dt \qquad (1)$$

Wavelet transformation can be looked as signal transmits through a bandpass filter, of which bandwidth is in proportion to the filter's central frequency. The filter has a settled relatively bandwidth. That is to say: wavelet transformation has different resolving power in different frequency. So wavelet transformation has self-adaptation analysis quality, similar to bandpass filter, which is the point that wavelet transformation surpasses standard Fourier transformation and short time transformation. System adopts MATLAB numerical value computation and visual software, which has powerful value computation, signal processing and graph display function. MATLAB integrate the calculation, visual data and program designing. In tradition ultrasonic detection, the original signal of Single-hole and flaw is similar. Digital ultrasonic detection device can not analyze them. In actual experiment, put wavelet transformation on single-hole, multi-hole and flaw limitation signal, then find the fourth and fifth layer signal of single-hole and flaw signal has distinct difference, which can be qualitative analyzed and judged. From single-hole and multi-hole contrast analysis curve, the hole-signal has much similar with remnants signal in fifth layer.

Radar signal processing based on wavelet transforms

Artificial intelligence is based on the technology to the knowledge expression, the gain and the inference, and expert system is a important technology in the artificial intelligence domain. The main essential factors of expert system are: Knowledge expression, knowledge gain, knowledge library. The structure of expert system is: the knowledge library —expert knowledge in the concrete domain, generally expressed with the rule and the fact; the inference machine—the inference tool which processes in the expert domain, realizes inference to the knowledge library; explains system—will expresses the inferential result in the language which is understand by human. The expert systems of radar signal data analysis include: The real-time supervisory system- provides the surveillance to each kind of data (for example each kind of transaction data in money market), each kind of change (for example transaction change in money market) regarding the money market, and makes the corresponding response according to the environment change; the data explanation system-establish effective model according to massive data which comes from the various aspects of money market, and provides each kind of data explanation to make it understand the movement condition of the money market.

Generally speaking, radar echo signals are usually noisy signals, so the detection of radar signals is actually noise reduction processing of radar echo signals. Due to the existence of various external interference signals, the signal-to-noise ratio of echo signals is usually relatively low, and the time-frequency local characteristics of wavelet analysis determine its wide application in the field of radar target detection PW. In essence, wavelet denoising is to achieve the purpose of denoising by some processing of rough resolution approximation and detail component on scale. First of all, the signal wavelet decomposition, the noise is usually included in the signal of high frequency components, so threshold method can be used to deal with each layer of wavelet coefficients, and then reconstruct the signal. Suppose the echo signal received by the radar is:

$$x(t) = s(t) + n(t) \qquad (2)$$

where s(t) is the target signal and n(t) is the noise, which is usually processed as Gaussian white noise.

The basic steps of wavelet width denoising are as follows:

(1) Select appropriate small sweep decomposition layers, and x(t) takes the discrete wavelet transform, namely

$$\begin{cases} c_{j+1,k} = \sum_m c_{j,m} h_{m-2k} \\ d_{j+1,k} = \sum_m c_{j,m} g_{m-2k} \end{cases} k = 0,1,\cdots,N-1 \quad (3)$$

where $C_{j,k}$ and $D_{j,k}$ are scale coefficient and wavelet coefficient, j is decomposition layer number, N is sampling point, and h and g are orthogonal filter Banks.

(2) The wavelet coefficients of each layer are denoised by threshold value. The commonly used threshold processing methods include hard threshold method and soft threshold method. The hard threshold method can retain local features such as the edge of signal, while the soft threshold processing is relatively smooth. In order to overcome the defects of soft and hard thresholds, the improved wavelet threshold function is adopted, and its expression is as follows:

$$\hat{d}_{j,k} = \begin{cases} 0 & |d_{j,k}| < T_L \\ \mathrm{sgn}(d_{j,k}) \dfrac{(|d_{j,k}| - T_L)^r T_H}{|T_H - T_L|^r} & T \le |d_{j,k}| \le T \\ d_{j,k} & |d_{j,k}| > T \end{cases} \quad (4)$$

where σ is the standard deviation of noise, $T = \sigma\sqrt{2\lg N},\quad T_L = 0$ T According to the experiment, when T_L = 1/10T and r=1.5, the signal noise reduction effect is good.

(3) According to the scale coefficient of the j-th layer and the wavelet coefficient of the 1-j layer obtained by wavelet decomposition, the signal after noise reduction is obtained by signal reconstruction, i.e.,

$$c_{j-1,m} = \sum_m c_{j,m} h_{k-2m} + \sum_m d_{j,m} g_{k-2m} \quad (5)$$

Root Mean Square Error (RMSE), SNR and PER were selected as evaluation criteria for signal noise reduction effect, where $x(n)$ represents the original signal and $x(n)$ represents the signal after noise reduction.

$$RMSE = \sqrt{\tfrac{1}{N}\sum_{n}\left|x(n) - x(n)\right|^{2}} \qquad (6)$$

$$SNR = 10\lg\left[\frac{\sum_{n} x^{2}(n)}{\sum_{n}\left|x(n) - x(n)\right|^{2}}\right] \qquad (7)$$

$$PER = \sqrt{\frac{1}{N}\sum_{n} x^{2}(n)} \Big/ \sqrt{\frac{1}{N}\sum_{n} x^{2}(n)} \qquad (8)$$

Experiments

Orthogonal wavelet was selected to conduct 5-layer decomposition of if signal containing noise, and soft threshold, hard threshold, Yasser threshold and improved Firm threshold were respectively adopted to de-noise the signal, and the signal waveform shown in Fig.1 is obtained. The noise reduction parameters of noisy if signal are shown in Fig. 1. As can be seen from Fig.1, compared with other threshold methods, the improved threshold method has a smaller root-mean-square error, a higher signal-to-noise ratio and an energy ratio, indicating that the threshold method can effectively approximate the localization characteristics of if signals and further improve the detection performance of radar. This threshold method is used in signal noise reduction processing.

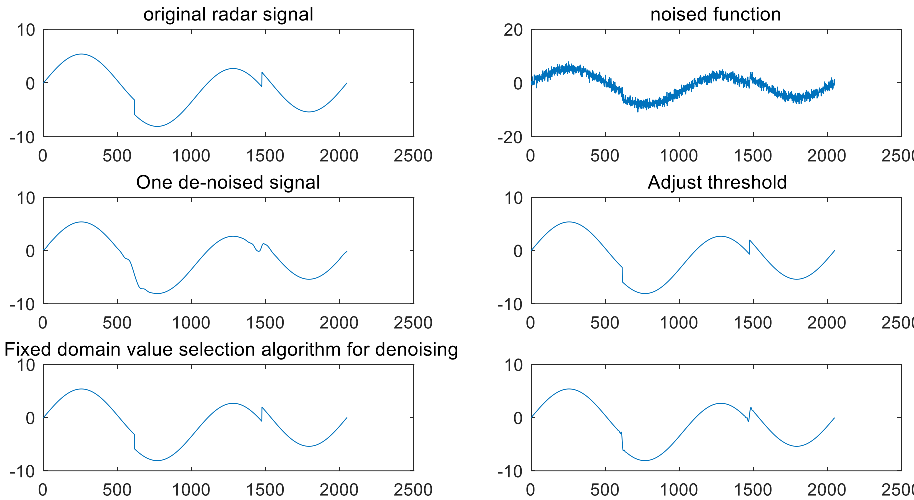

Figure No. 1: Radar signal processing

CONCLUSION

The application of wavelet transformation in ultrasonic detection without loss is more and more often, which as a new signal processing method. Wavelet transformation can decompose the signal which has different frequency in different Subspace. It can distinguish the signal's frequency Component in any position. In actual signal processing, wavelet transformation can be used for analyze, identify and judge signal.

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