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Construction of Distributed Processing System for Marine Radar Signals

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Abstract: With the rapid development of my country's national economy and the continuous increase of domestic and foreign trade volume, maritime transportation has become more prosperous. Radar signal processing technology is the core technology for marine radar to detect maritime targets, and plays a vital role in safe and efficient maritime transportation. The purpose of this paper is to study the construction of distributed radar signal processing system, introduce the basic structure, signal model and flow signal processing algorithm of distributed radar system, analyze the influence of time delay and amplitude phase error. This paper introduces the traditional node width and phase error correction methods for distributed radar systems, and analyzes the algorithm for the two situations of intra-node and inter-node, and analyzes the effectiveness of the algorithm. Verified by simulation experiments. Finally, the results of the radar wave signal processing ability are compared and tested, and the results show that the signal processing integrity rate of the traditional system is lower than 90%. The signal processing integrity rate of the system constructed in this paper is close to 100%, so the distributed marine radar signal processing system constructed in this paper is obviously better than the traditional radar signal processing system.

1. Introduction

With the rapid growth of my country's national economy and the increasing expansion of domestic trade, ocean transportation is becoming more and more prosperous. As the core of marine radar detection of marine information, radar signal processing technology plays a pivotal role in the safe transportation of oceans [1]. Radar technical information preprocessing equipment is mainly responsible for the collection of radar technical return wave information and a series of clutter data processing. It has a high demand for real-time. The development of VLSI technology, especially the emergence of large-scale programmable logic devices, has brought new breakthroughs to the digital processing of radar signals [2].

With the rapid development of information technology, digital signal processing technology is becoming more and more perfect. Rosenberg L studies three sparse signal separation formulations using the short-time Fourier transform as a dictionary. This method has been shown to effectively separate stationary and moving targets from sea clutter, but it relies on the tuning of different parameters. The first part of this work looks at how to choose these parameters that are critical to achieve good separation. Then some practical detection schemes that allow to control the false positive rate are proposed. Algorithmic performance is demonstrated by Monte Carlo simulations and synthetic targets injected into the Ingara medium-angle-grazing sea clutter dataset [3]. Pastina D discusses the use of global navigation satellite systems (GNSS) as transmitters of opportunity in passive bistatic radar systems for maritime surveillance. The main limitation of this technology is the limited power budget provided by navigation satellites, making it necessary to define innovative moving object detection techniques tailored specifically to the system under consideration. To this end, this paper proposes a long integration time technique, which is able to collect signal energy over a very long time interval (tens of seconds), allowing the retrieval of suitable signal-to-noise ratio levels for detection purposes. Consider first a local plane-based technique that provides object detection in a plane representing the cross-section of the sea area covered by the radar antenna. As a sub-optimal solution to the achievable integral gain, but more efficient from a computational point of view, the second technique is considered to work in the conventional bistatic range and the Doppler plane (based on the fundamental plane). Results on synthetic and experimental datasets demonstrate the effectiveness of the proposed technique [4]. The research on the distributed processing system of marine radar signals is of great significance for improving the performance of marine radar systems and ensuring the safety of marine traffic and navigation.

Based on the ADSPTS201S chip, this paper designs and implements a distributed processing system for marine radar signals. On the basis of the system implementation, according to the requirements of the information fusion unit of the distributed networked radar system, the parallel processing method is used to process the networked radar signal, and the algorithm design and task division are carried out effectively. The realized hardware system has the characteristics of scalability and real-time performance, and can be applied to other fields of networked radar signal processing. The development of this system adopts some advanced technologies in the fields of high-speed data acquisition, radar testing, software radio, etc., which has certain significance and value for the application and development of these technologies.

2. Research on Distributed Processing System of Marine Radar Signals

2.1. Rayfa Signal Detection

As early as the 1940s, the advent of filter technology improved the measurement characteristics of radar signals. Since then, due to the emergence of statistical analysis technology, the standard radar signal measurement process has gradually formed. But at present, the radar signal measurement process is mainly faced with two problems: one is to judge whether the target environment is disturbed too much. There are mainly two types of methods for this problem, information measurement based on statistical characteristics and information measurement based on target characteristics [5-6]. Statistically based measurements measure objects by differences in information distribution and background disturbances. The measurement based on target characteristics uses a variety of different target characteristics to achieve target measurement, mainly including target detection based on feature extraction and target detection based on model prediction; another important issue is to control the false alarm rate. In terms of false alarm control, there are mainly three methods: parameter constant false alarm rate, non-parametric constant false alarm rate, and clutter map detection based on multi-detection data. In the process of target detection, the false alarm rate needs to be kept within a certain range, and the main role of CFAR is to create an adaptive detection threshold to control the false alarm rate [7-8].

2.2. Research Goals and Design Principles of Distributed Processing Systems

The main design goal of the distributed processing system proposed in this paper is to design and develop a software system based on a computer cluster under the Windows operating system [9-10]. The distributed processing system designed in this paper has the following six design principles:

First, there is no limit to the number and performance of PCs participating in distributed computing activities. The system can automatically detect computer hardware activity and assign appropriate computing tasks and computing characteristics to computer server processes in a cluster.

Second, the data analysis process is open, and users can define the data analysis process by themselves, and there is no limit to the complexity of the integration process.

Third, it supports modification of the entire computing process, which can modify the operation of any computing device in any computing process.

Fourth, the system supports transparent data access, and the data processing process in the distributed processing system is not significantly different from that of the computer.

Fifth, in order to avoid the burden of remote data access and result mixing as much as possible, the system adopts a conservative distribution method, so that the computing unit with processing load is completed on the computing server as much as possible.

Sixth, distributed systems try to use coarse interfaces to complete object transfer to avoid more structure [11-12].

2.3. Influencing Factors of Radar Target Feature Recognition

(1) Background complexity

The background variation range of radar targets is very large, and it is difficult to model accurately. The background may include targets or non-interesting targets, and these targets have no template or model in the target recognition algorithm [13-14]. If the designed algorithm can ignore these background changes, the recognition effect may be improved to a certain extent, but if the target feature and the background feature interact, ignoring the background change will reduce the detection ability of the target. Therefore, the practice of ignoring background changes may not be appropriate [15-16].

(2) The existence of confusing targets

The description of the obfuscated target is more difficult. Since the detailed information of the obfuscated target is not known in advance, and there is no way to model it, it is even impossible to have enough feature samples of the obfuscated target to build rich background database information. The usual solution is that the recognition system treats the confusing target as a rejected target [17-18].

3. Design and Development of Distributed Processing System for Marine Radar Signals

3.1. Setting up the System Software Development Environment

(1) STM32 series development method selection

Embedded system software development mainly includes two development methods, direct manipulation of registers and the use of firmware function libraries. Most 8-bit or 16-bit mid-to-low-end MCUs usually use direct manipulation of registers for software development. The main frequency of these embedded microcontrollers is low, and the execution efficiency of their program codes is low. The direct operation of registers can improve the program execution efficiency.

(2) Construction of a development environment based on KeiIuVersion

The software design, development and debugging of this solution are based on KeilµVersion5.29 and ANSIC11 standards. C language occupies an absolute dominant position in the field of embedded software development, while the three integrated development environments of Codewarrior, IAR and Keil are used in embedded software The field of software development is the absolute mainstream platform.

(3) STM32F767IGx boot analysis

In the STM32F767IG6 microcontroller used in this article, startup_stm32f767xx.s is a boot source file written in assembly language. It is mainly responsible for completing some initialization and configuration work, providing conditions for the loading of the C language main function. The boot file includes a code segment, One read-only data segment and two read-write data segments.

3.2. Signal Processing Flow

Two seekers and a set of signal processors are used as the test system of the missile distributed coherent synthesis radar.

The signal emitted by seeker 1 is:

$$x_1(t) = \cos(2\pi F_1 t + \pi\mu t^2) \tag{1}$$

The signal emitted by seeker 2 is:

$$x_2(t) = \cos(2\pi F_2 t + \pi\mu t^2) \tag{2}$$

In the formula, F1=16.485GHz is the launch signal frequency of missile 1, F2=16.515GHz is the launch signal frequency of missile 2, µ is the frequency modulation slope, and t is the launch time series.

Two seekers are planned to be used as the test system. Taking the echo signal received by seeker 1 as an example, the signal processing includes: 1) The intermediate frequency echo signal is converted into a digital signal through AD conversion, and f1 and f2 are used as the original signal respectively. The vibration signal is separated from the echo signal sent by seeker 1 and received by seeker 1 and the echo signal received by seeker 2 and received by seeker 1, and the separated signals are filtered and extracted to obtain the baseband I and Q signals; 2) The I and Q signals are synthesized into complex signals for pulse compression and coherent accumulation respectively; 3) The Doppler dimension data of the target is extracted from the accumulated data for coherent parameter estimation, and the final realization is achieved by complementing the delay phase processing. Coherent synthesis is used to verify the SNR gain in MISO mode, MIMO mode and fully coherent mode.

3.3. Radar Signal Acquisition Preprocessing

In this test system, two seekers and a set of signal processor are planned to be used as the test system. The same preprocessing work is done for the echo signals received by each seeker. Taking seeker 1 as an example, the missile-borne distributed coherent synthesis radar signal acquisition preprocessing module mainly completes the following functions: The analog echo signal is collected by the gate; the multi-channel digital signal separation processing is performed on the echo signal received by the seeker 1, and the echo signals of the seeker 1 sent and received and the seeker 2 sent and received respectively are obtained, and then the The signal after channel separation is filtered and processed by 8 times decimation to obtain a digital signal with a low data rate; each PRT data after filtering and decimation is ping-pong buffer; each PRT data is subjected to 2048-point pulse compression processing, and a CPI is a total of 8 The pulse pressure results of each PRT are buffered in FIFO and sent to the signal processing board DSP for further processing.

4. Design and Research of Distributed Processing System of Marine Radar Signals

4.1. Signal Acquisition Preprocessing Module

As shown in Figure 1, the signal acquisition preprocessing module is mainly composed of the following modules: PRT wave gate acquisition module, Channel_separation digital channel separation module, Data_buff data buffer module and pulseCompression pulse pressure module. The four modules correspond to the above signal acquisition modules respectively. Four functions of the preprocessing module.

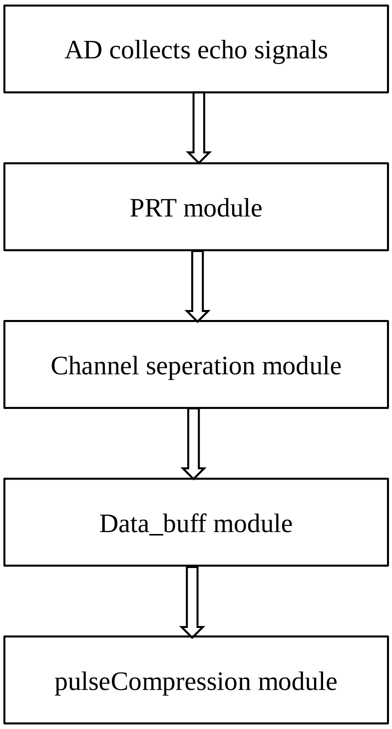

Figure 1. Signal acquisition preprocessing module

PRT module: This module is mainly used to control the sampling gate and obtain PRT data from the echo data collected by AD.

Channel separation module: This module mainly completes digital channel separation and filter extraction processing.

Data_buff module: This module completes the buffering of a PRT data through ping-pong processing.

pulseCompression module: This module mainly completes the pulse compression processing of a PRT data after filtering and extraction.

4.2. CPCI Power Monitoring Card Acquisition Accuracy Test

The CPCI power monitoring card needs to monitor four power supply voltages, which are 4V±1V, 10V±2V, -10V±2V, 25V±4V. Since the front end of AD7607 uses the isolation op amp AD202 and the voltage divider resistor to adjust the input signal, and the isolation op amp and the voltage divider resistor have certain errors, the measured voltage value contains a certain system error. In order to obtain accurate measurement values within the measurement range, it is necessary to fit the measurement results. The table below lists the measurements and errors without fitting.

Table 1. CPCI power monitoring card voltage measurement accuracy test

Aisle	Standard value (DMM) (V)	Measured value (V)	Error (percent)
CHI	4.03	3.88	0.83%
CHI	4.25	4.56	0.82%
CHI	4.65	4.87	0.78%
CHI	4.93	5.21	0.81%
CHI	5.06	5.66	0.83%

It can be seen from Table 1 that the error of the direct measurement value is large, even reaching 0.83%, which is mainly caused by the inaccurate resistance of the isolated op amp with DC bias and voltage divider resistors.

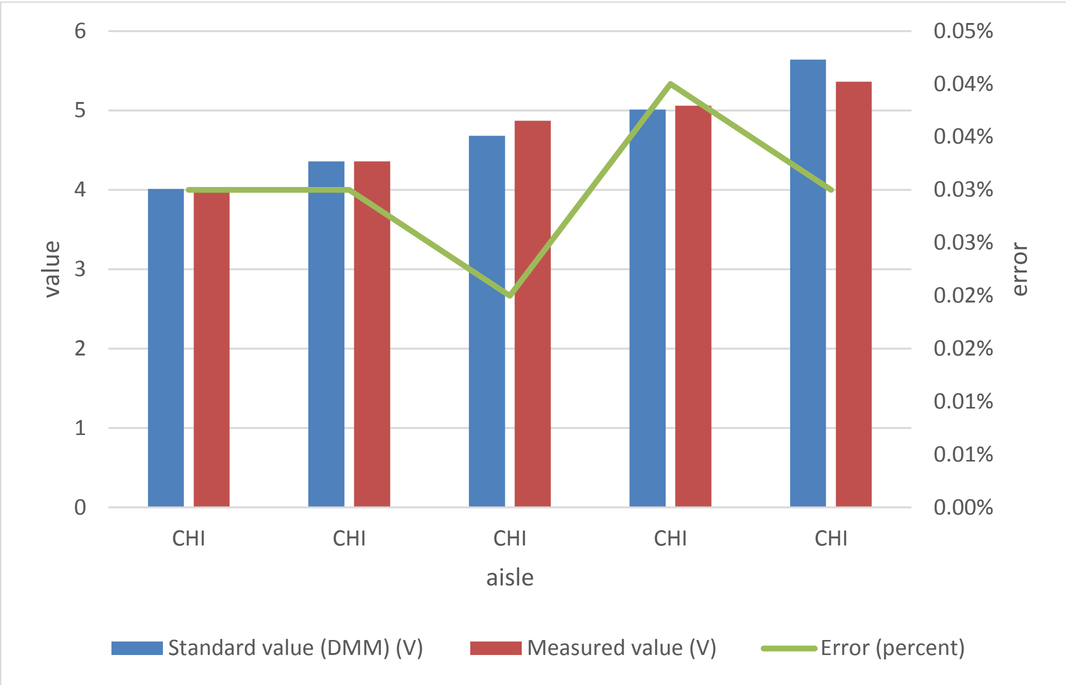

Figure 2. CPCI power monitoring card accuracy test after voltage error calibration

From the experimental data shown in Figure 2, it can be seen that the error of the measurement result after fitting is controlled within 0.2%, which meets the measurement accuracy of 0.5% required by the task. For the other three input channels, repeat the above experiment to complete the correction of the measurement results. Experiments show that the measurement error after fitting is controlled within 0.5%. To sum up, the hardware of the CPCI power monitoring card can work normally, and the AD acquisition accuracy can meet the task requirements.

4.3. Simulated Radar Signal Test

The radar wave signal processing capability of the construction and design of the proposed radar surface distributed signal processing system is evaluated through simulation data, and the experimental results are compared. The simulation test results are shown in Table 2.

Table 2. Radar signal processing performance test results

Test serial number	Signal processing integrity rate of traditional systems/%	The signal processing integrity rate of the system in this paper/%
1	87.6	97.8
2	86.4	98.9
3	78.9	98.7
4	80.5	99.5
5	83.4	99.6

Comparing the data in Figure 3, it can be seen that the signal fidelity rate of the traditional system is lower than 90%, while the signal fidelity rate of the system in this paper is close to 100%. Radar waves are significantly better than traditional radar signal systems.

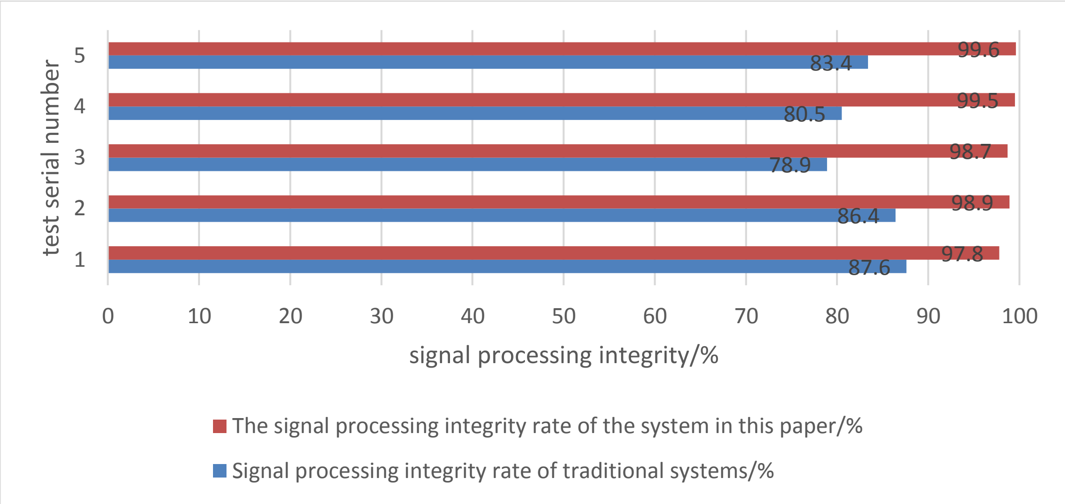

Figure 3. Radar signal processing integrity ratio comparison

5.Conclusion

With the continuous improvement of radar system and the continuous development of radar data processing technology, radar target recognition has been paid more and more attention by researchers. The role of radar is no longer simply to judge whether there is a target, but to "distinguish" the type of target. Using radar target recognition theory, the type of radar target can be identified and the influence of sea clutter can be reduced. Therefore, using radar target feature information to improve radar signal detection performance has important theoretical research and practical application significance. Based on the content of the completed work, the thesis plan still has some work to be enriched and perfected. For example, the hardware communication interface integrated in the design of this paper is not perfect, and communication interfaces such as RS485 and dual CAN can be integrated to further improve the compatibility of the system.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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