

Address Query and Signal Processing System Based on Artificial Intelligence Sensor Array in Time Domain

Haixia Guo*

School of Computer Science and Mathematics, Harbin Finance University, Harbin 150036, Heilongjiang, China

With the continuous development of the national economy and national defense technology, array address query signal processing systems are increasingly being applied in various fields such as communication, radar, seismic exploration, radio astronomy, wireless communication signal monitoring and management, mobile communication, navigation, medicine, etc. However, when multiple signals with the same beamwidth appear simultaneously, traditional array-based signal processing methods cannot effectively distinguish multiple signals. Artificial intelligence (AI) sensor array can address query and signal processing, and is an emerging information processing mode that breaks through the Rayleigh limitation of traditional methods, thereby achieving target analysis and localization. This study applied the array time-domain technology in AI sensors to address query and signal processing systems. For the construction of an array address query and signal processing system, multiple signal classification algorithms were used to calculate signal fluctuations, and four data features of the two were compared and analyzed. The results showed that the proposed intelligent array address query and signal processing system can solve the problems existing in traditional methods, and the algorithm used can greatly improve the resolution ability of the array antenna and ease the restrictions on column structure. The time-domain address query and signal processing system of AI sensor arrays can maintain an average stability of over 86%, with a minimum time requirement of 32 seconds; accuracy generally consistent at over 90%, and an average number of 51.8 more than traditional systems in terms of universality. This plays a very important role in the research and development of both civilian and military equipment, and can facilitate further upgrading and development of the respective technology.

Keywords: Address Signal Processing System, Artificial Intelligence Sensor, Array Time Domain, Multiple Signal Classification Algorithm

1. INTRODUCTION

With the development of technology and the continuous progress of society, there has been a gradual transition to an information society, which has led to an increasing demand for complete access to distributed, heterogeneous information. One of the most important features of address query and signal processing systems is that they have to handle a huge number of query requests simultaneously, so efficient querying is crucial. However, conventional query processing algorithms can only solve the problem of linear time invariance.

When the number of sample points is small, this can lead to inaccurate spectrum estimation and low accuracy. Due to the continuous development of technology, technologies such as address lookup and signal processing have become increasingly mature, and the costs incurred by applications have decreased while reliability has become greater. At present, address query and signal processing systems can be integrated effectively with control technologies such as AI sensor arrays in the time domain, thereby improving system stability and giving it a greater number of functions.

When modern science and technology are combined with address inquiry and signal processing, a new processing

*Email: 15822158548@163.com

method for AI sensor array address inquiry signal processing system can be formed. Many scholars have examined the effectiveness of this processing method in various fields. Haeb-Umbach [1] proposed a highly acceptable speech processing algorithm and applied it to multi-channel acoustic echo suppression, microphone array processing, denoising, and other aspects. He constructed a complex speech and language statistical model and revealed the important role of signal processing in this field. Zhong [2] believed that with the development of cloud services and data center applications, a direct probing reception scheme based on digital signal processing technology is possible. Zhong found that this technology can meet the requirements of low cost and high efficiency in data transmission rate, successfully addressing the shortcomings of existing devices. Mishra [3] stated that millimeter wave communication is a preferred technology in short-distance wireless links. Focusing on signal processing in the millimeter wave joint radar communication system, he achieved the optimal balance between communication and radar functions. He believed that signal processing technology is the key to achieving millimeter wave joint radar communication systems, and this band is expected to be applied to short-range radar. Liu [4] focused on dual function multi-input multi-output radar communication processing systems. By flexibly balancing radar and communication performance, weight optimization was carried out, and low complexity algorithms were introduced into the evaluation of data results. Liu studied the effectiveness of the waveform design method and provided the optimal solution. Hu [5] regarded the information transmission of multiple radiation sources and sensitive sources as a continuous surface. Under the LOS transmission condition, a LIS (large intelligent surface) receiving antenna array was used to match and filter it, and a similar self-symplectic function was used to approximate it. It was also found that the sampling lattice that minimizes the surface area of each antenna while obtaining an independent signal dimension is hexagonal. The new processing methods of signal processing systems can be used in many fields, but the technologies combined with them need to be continuously developed and innovated in order to optimize the system.

Many scholars believe that the emergence of AI sensor arrays in the time domain has brought new vitality to the system, improving it significantly. Therefore, it is necessary to conduct in-depth research on its functions. Gao [6] suggested that acoustic pulse Doppler signals generate reverberation and distortion during transmission, and conducted numerical simulation and analysis of the acoustic pulse Doppler effect. On this basis, through the understanding of wave propagation mechanism, a novel optical fiber acoustic sensor was developed as a prototype for the measurement of partial discharge location. It can achieve an accuracy of less than 5 cm, laying the foundation for accurate positioning of partial discharge positions. Li [7] proposed a spray-type gas sensor array based on silver nanoparticles and all carbon nanostructures, and applied it to a variety of targets. The results showed that it has good scalability and adaptability on different targets. His study offered a new solution for online detection in fields such as portable electronic products and human-computer interaction. Li [8] provided a comprehensive review of the

development and current status of sensor arrays. By analyzing and designing sensor arrays and instruments, he transformed chemical or physical properties related to molecules or ion species for the detection and analysis of subtle changes in the chemical environment, developing a highly sensitive chemical sensor. Huang [9] believed that micro-pressure sensors can quickly detect subtle pressure changes and have important application value in AI and other devices. On this basis, it was found that a new type of highly sensitive pressure sensor would have advantages such as fast response, low power consumption, small detection range, and good stability. Gao [10] believed that the optical fiber sensor has various advantages, such as good sensitivity, strong anti-electromagnetic interference ability, small size and good insulation performance, and is a good linear acoustic partial discharge location method. A set of ultrasonic detection system for partial discharge in transformer oil was established by using 2×2 Fabry-Pérot cavity optical fiber sensor array and steering response power method. The experimental results showed that the fiber optic sonar array had good directionality and can achieve precise positioning. The aforementioned research indicates that the application of sensor arrays in AI and other fields is becoming increasingly widespread, which has played an important role in driving the development of address query signal processing systems.

With the development of AI sensor arrays in the time domain, address query signal processing systems are increasingly being used. In particular, the successful application in military electronic warfare has led to the rapid development of wireless communication signal direction finding technology and sparked global attention to direction finding technology and equipment. Array signal processing [11] can be used to analyze and process spatial signals, and has become an important means of finding the direction of radio frequencies.

2. METHOD OF ADDRESS QUERY AND SIGNAL PROCESSING SYSTEM

2.1 Definition of Address Query and Signal Processing

Address query includes the functional module of address name query, which is essentially a query for Internet Protocol Address addresses. Internet Protocol Address is an identifier that allows information to be sent between devices on a network, containing location information that allows devices to communicate. Internet Protocol Address provides a method for address lookup, which is an important part of the operation of the Internet.

A signal processing system is a network application platform established using signal processing technology [12]. The main function of this network application platform is to organize, analyze, and process relevant data information, and extract useful data information from it. Firstly, in order to fully explore useful data information, it is necessary to first process and record the medium signal, and then perform comprehensive processing work such as extraction and conversion. Secondly, the signal processing system can

convert different signals into text that can be recognized by the machine, ensuring the smooth transmission of signals and the convenience and efficiency of signal processing. Once again, the system can establish a connection with the external world on the computer, enabling it to communicate smoothly with the external world, and can effectively and efficiently process these signals on this basis. It also has separate storage capabilities that can effectively execute multiple individual programs and generate corresponding data instructions. Finally, due to the differences in the software used in signal processing systems, they are able to process different types of signals and simulate various complex signals.

2.2 Address Query and Signal Processing Methods and Current Status

There are two types of intelligent signal processing methods: classical and modern. The classical method based on Fourier transform can handle only the problem of linear time invariance. The solution of nonlinear time-varying problems is an important component of modern methodology. Traditional spectral estimation algorithms use a “windowing” operation when processing sampled sequences, and set the data outside the window to 0. Therefore, when the number of sampling points is small, traditional spectral estimation methods are no longer reliable. Modern spectral estimation methods [13] are based on models and model the sampled data to better indicate the global characteristics of random signals. Each has its own unique characteristics: traditional spectral estimation methods are simple, have low computational complexity, and yield very good results at multiple sampling points. However, when the sampling time is short, the resolution of traditional methods is not high, so it is better to use modern spectral estimation. Compared with traditional methods, this method has better stationarity and better handling of nonlinear time-varying characteristics.

The current status of address inquiry and signal processing is closely related to the development of a country’s science and technology. It mainly involves implementing digital processing, converting analog signals such as images, sound, and video into corresponding digital signals, and then processing them with corresponding systems to improve control effectiveness. Address inquiry and signal processing have been widely applied in many fields such as audio devices, the Internet of Things, automotive electronics, industrial control, and other fields.

2.3 MUSIC Algorithm in Time Domain of AI Sensor Arrays

The intelligent sensor [14] is equipped with a microprocessor that is able to collect, process, and exchange information, achieved by integrating the sensor with the microprocessor. The time domain of the array combined with the sensor and the microprocessor uses time as the independent variable, that is, the horizontal axis represents time and the vertical axis

represents the change of the signal. Its dynamic signal is a function that gives the value of a signal at different times, which can serve as a queue to describe address queries and signal processing. Array signal processing is becoming an important branch of signal processing. Its basic task is to analyze and process all detection systems, space transmission systems, and airspace signals. It is a sensor array consisting of multiple sensors arranged in a specific manner. At the same time, the array method is used to acquire spatial signals and obtain discretization observations in the spatial domain. Therefore, by means of the Music (Multiple Signal Classification) algorithm, the obtained observations can be divided into multiple signal subspaces.

The Music algorithm is also known as a multi-signal classification algorithm [15]. The basic idea is to decompose the covariance matrix of any array output data into eigenvalues. The feature vectors corresponding to different eigenvalues form mutually orthogonal signal subspaces and noise subspaces. The eigenvectors corresponding to large eigenvalues form a signal subspace, while the eigenvectors corresponding to small eigenvalues form a noise subspace. After that, the orthogonality between the two subspaces is used to estimate the direction of arrival (DOA estimation or spatial spectrum estimation) of the signal. It is assumed that there is an N -element equidistant linear array with a spacing of d and a signal wavelength of λ , and r sources in space, the received observation signal can be expressed as follows by Formula (1):

$$A(t) = \sum_{i=1}^r B_i(t)X(\theta_i) + S(t) \quad (1)$$

where $B_i(t)$ is the i -th signal, and θ_i is the incidence angle of the i -th signal in space, which can be expressed by Formula (2):

$$X(\theta_i) = [1, e^{i2\pi d \sin(\theta_i)/\lambda}, \dots, e^{i2\pi(S-1)d \sin(\theta_i)/\lambda}]^T \quad (2)$$

The received signal can be further represented by formulas (3) and (4):

$$X = [X(\theta_1), X(\theta_2), \dots, X(\theta_r)] \quad (3)$$

$$B(t) = [B_1(t), B_2(t), \dots, B_r(t)]^T \quad (4)$$

In formulas (3) and (4), a sufficient and necessary condition for a square matrix to be similar to a diagonal matrix is that X is a normal matrix (real or complex). For the real matrix X , if $X = XX^T$ is satisfied, then X is a normal matrix; for complex matrix X , if $X^*X = XX^*$ is satisfied, then X is a normal matrix.

The covariance matrix is shown in Formula (5):

$$\begin{aligned} R &= E[S^*S^T] = E[(XB(t) + N(t))T] \\ &= X^*R_bX^T + R_n = X^*R_bX^T + \sigma^2I \end{aligned} \quad (5)$$

In Formula (5), σ^2 is the variance.

Since the covariance matrix is hermitian matrix ($Y_S^H = Y_S$), which is a normal matrix, the covariance matrix Y_S is also similar to the diagonal matrix:

$$Y_S = Q(\Lambda + \sigma^2I)Q^H \quad (6)$$

In Formula (6), the r element on the diagonal of Λ is positive, and the others are zero.

3. DESIGN OF ADDRESS QUERY AND SIGNAL PROCESSING SYSTEM BASED ON AI SENSOR ARRAY IN TIME DOMAIN

The address query and signal processing system has been widely applied in many fields and has developed rapidly. It can convert analog signals such as images, sound, and video into corresponding digital signals, thereby achieving address query and signal processing [16–18]. During this process, digital chips are used to analyze and process signals. The set values are used to issue corresponding instructions and provide feedback on the most realistic situation. In order to improve the processing efficiency and stability of the system, the effective combination of digital signal processing with fast processing speed, strong anti-interference ability, and accurate address query with AI sensor array time-domain can better display the address query and signal processing system.

3.1 System Design Plan

In address inquiry and signal processing, methods such as computer address inquiry, signal acquisition, processing, and control are commonly used.

(1) Implemented by a general-purpose computer

A data collector connected to the PCI (Peripheral Component Interconnect) bus can be used to input the address provided by the computer, and the collected signal, into the microcomputer for processing. These can be displayed on the measurement and control platform. Due to its large volume and high cost, the system cannot be operated offline, so it is suitable only for the analysis of algorithm simulation.

(2) Microprocessing system with microcontroller as the core

The microcontroller has a simple structure making it easy to implement human-machine interfaces, but its memory capacity is very small. Moreover, von Neumann's bus structure can significantly decrease the system's computing speed, especially in multiplication operations. Moreover, address-spanning operations are complex, making it difficult to meet the requirements for real-time data processing. Therefore, it is suitable only for relatively simple digital signals.

(3) Universal DSP (Digital Signal Processing) chip

Compared to microcontrollers, DSP has more advantages and is suitable for signal processing and address inquiry. DSP chips have advantages such as high speed, high computing speed, and high computational efficiency. They use the Harvard architecture internally, greatly improving the parallelism of microprocessors. The application of DSP technology makes real-time signal processing possible.

(4) Completed using a special DSP chip

At present, many specialized chips have been launched for FFT (Fast Fourier Transform), FIR (Fine Impulse

Response) filtering, convolution, and other applications. Users only need to provide input data and, through simple combinations, they can obtain results at the output end. It is mainly used in situations where speed is essential. Its signal processing algorithm is implemented by hardware and has been fixed in the chip by the manufacturer. Users cannot change it, and it is not suitable for address queries. Therefore, its application is greatly limited.

(5) Implemented using Complex Programmable Logic Device (CPLD)/FPGA (Field Programmable Gate Array)

Due to the development of CPLD/FPGA, people can utilize products and development platforms from companies such as Altera and Xilinx, as well as development languages such as Verilog and VHDL (Very-High-Speed Integrated Circuit Hardware Description Language), and apply specific signal processing algorithms with hardware through software programming. This method is flexible but requires a lengthy and difficult amount of research and development.

Overall, the use of ordinary DSP chips as the core processor has unparalleled advantages. Firstly, DSP has good real-time performance, and its computing speed is much faster than that of a regular CPU (Central Processing Unit). The digital signal processing system composed of DSP can meet the real-time requirements. Secondly, DSP is very flexible and usually does not require any modifications in its software programs. Its accuracy is high, and the device accuracy of analog circuits is difficult to exceed 10⁻³, while the device accuracy of digital systems can reach 10⁻⁵. Due to the low price, short development cycle, and complete development and debugging tools of ordinary DSP chips, ordinary DSP chips are usually chosen in practical applications. Meanwhile, due to the strict timing requirements and fast speed of CPLD, it can be programmed on-site and has good scalability performance. In this article, a DSP+FPGA architecture was adopted, which can fully leverage the advantages of both and complement each other. This enables a system to be designed to meet the needs of data processing while also providing greater flexibility. By changing the program in the FLASH memory inside the DSP, the control program is reconfigured. At the same time, CPLD itself is also a programming method that can be designed and included in the system. Therefore, this method has greater flexibility in terms of software and hardware configuration.

3.2 Architecture of Address Query System Based on AI Sensor Array in Time Domain

The address query system is an application data system that converts addresses expressed in everyday language into those corresponding to the Global Positioning System (GPS). Its demand background is that in the application network and real life, the addresses of merchants are basically described in natural language. When analyzing current application systems, in most cases, the description of addresses is in natural language. To determine its specific location, certain

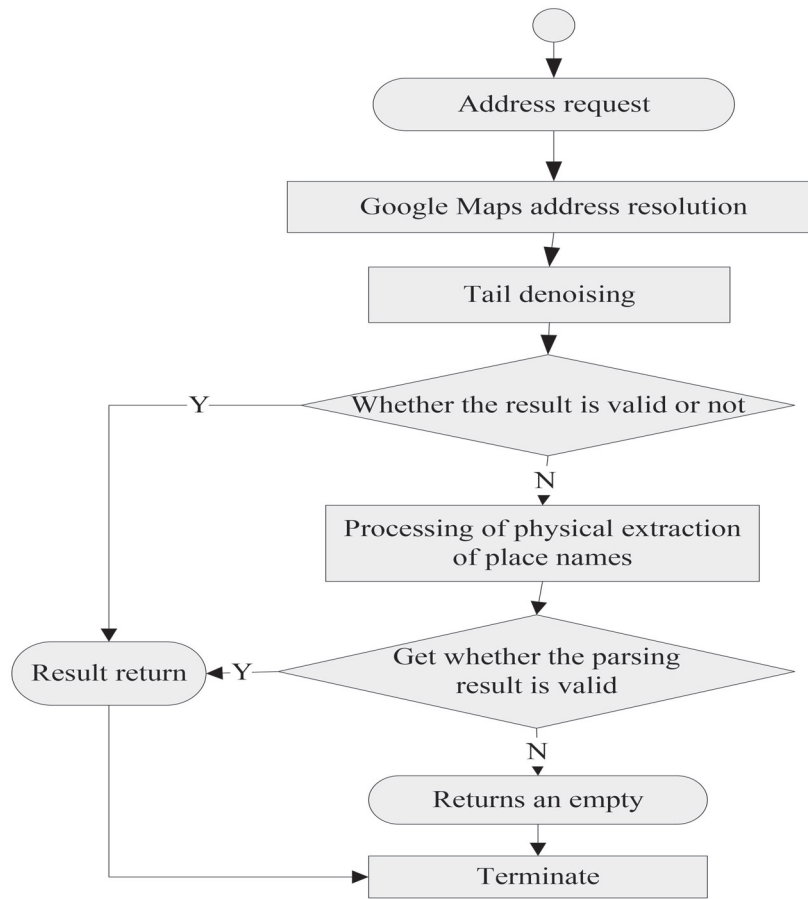


Figure 1 Overall architecture design of the address query system.

methods need to be used to achieve it. The address query system designed in this study automatically converts these addresses into clear GPS data. Combined with the GPS system, it can accurately ascertain the specific location of merchants, thereby improving the service quality of Location Based Services (LBS).

On this basis, in this study, a new solution was adopted and applied to practical scenarios. In order to effectively improve the recovery rate, the natural language address must be converted into legal GPS data, which requires the system to have a greater ability to analyze the language address, that is, noise suppression. To improve the accuracy of system operation, the system must be able to return GPS data completely and correctly, which can effectively improve the system's filtering and filtering ability. This requires a more efficient module to filter sentence similarity in the system. Hence, the system design is divided into two parts: request format processing and similarity calculation. The function of the request format subsystem is to format address requests from external sources, so that Google Maps can distinguish the required address information to the maximum extent possible. The similarity calculation subsystem processes and extracts the addresses returned by Google Maps, which enables it to provide users with the most accurate and realistic geographical location. Firstly, the "formatting" subsystem was used to filter and filter the noisy words in the request. After address analysis by Google Maps, the results were analyzed in terms of similarity. If the analysis result is valid, then it is returned

to the user. If it is invalid, the obtained place name entities are extracted from the starting point of the request, and then Google Maps is used to analyze the obtained place name entities and obtain a result. If the returned result is not optimal, the analysis is repeated until a valid and correct conclusion is obtained. The entire system architecture is shown in Figure 1.

3.3 Time Domain Signal Processing Module Based on AI Sensor Array

In this study, FPGA was used to control the system interface and time. The FPGA of the XC5VLX50T model has 480 user input and output interfaces, which can be configured according to different standards. It can provide up to 2160 kilobits of block memory and 480 kilobits of dispersed memory. The single chip integrates 12 adapter IO (Input output) modules, fully meeting the design requirements of the entire system. The interface part of the system involves the input and output of data, and is transmitted through optical fibers according to engineering needs. Baseband data comprising 48 channels is received from 3 ports, with 8, 24, and 16 transmission channels respectively, requiring a total of 3 receiving optical ports. To meet the application demands of multiple devices, a minimum of 3 optical ports for baseband data transfer are required. The result of processing requires two or more optical ports. Here, each processor is equipped with three fiber optic transceiver interfaces. The optical

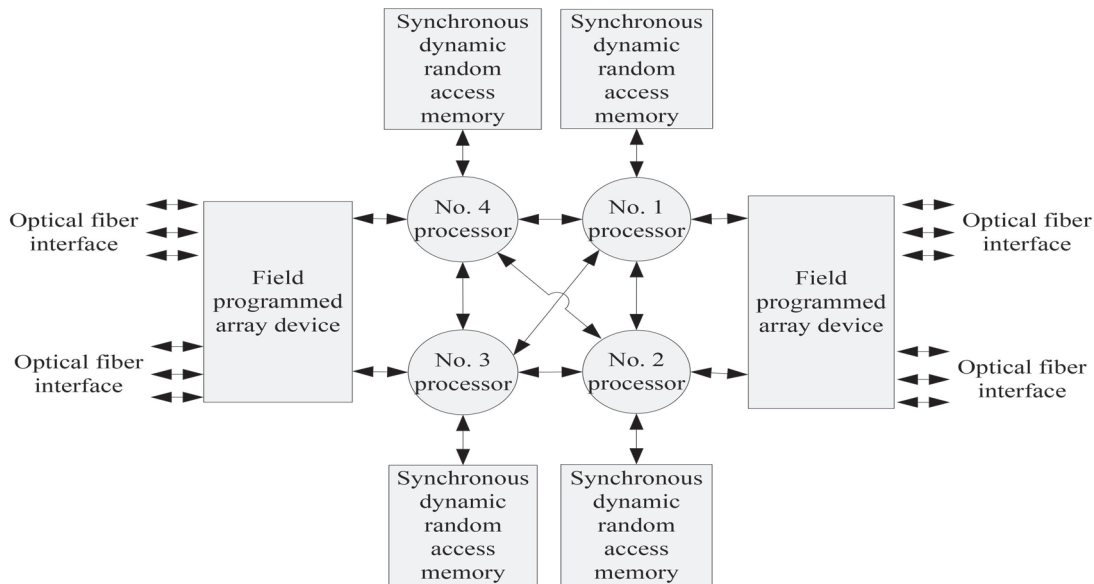


Figure 2 Diagram of signal processing system structure.

transceiver uses a RocketIO module, which is a high-speed serial transceiver that uses two pairs of differential signals for data transmission and reception. When sending data, the processor writes the data to the FIFO (First In First Out) of the FPGA through an external interface. Afterwards, the data is sent to other places through the RocketIO module via FIFO. When receiving data, it first enters the RocketIO module. After the conversion, it is written to the receiving FIFO of the FPGA, and the processor uses an external bus to read data from the receiving FIFO, which is then read into memory for processing. The components of the signal processing system are shown in Figure 2.

3.4 Specific Implementation of Address Query and Signal Processing System

In this study, the address query and signal processing system was tested and analyzed in terms of the overall system design and architecture, as well as algorithms for various parts. After completing the architecture design of the address query and signal processing system, and analyzing and testing the various functions of the system, the system was applied to various fields. Users only need to follow the process for operation. The successful design of this system provided users with a more convenient way to promote development and progress in various fields.

4. APPLICATION OF ADDRESS QUERY AND SIGNAL PROCESSING SYSTEM

4.1 Stability

Stability is a very important issue in applications such as address lookup and signal processing. Because of interference, the system can deviate from its state of equilibrium. Stability refers to whether, after the disturbance, the system can be

restored to its original equilibrium through self-adjustment after it disappears, thereby achieving stability. If it can recover, this indicates stability; otherwise, it means instability. Therefore, stability is not only a fundamental requirement of the system, but also a fundamental condition for operation. The stability of the AI sensor array time-domain address query and signal processing system was compared with traditional address query and signal processing systems. The comparison results are shown in Figure 3.

Figure 3 shows the stability comparison results for the time-domain address query and signal processing systems of AI sensor arrays and the six major fields of traditional address query and signal processing systems. From Figure 3, it can be seen that the stability based on AI was generally above 86%; the lowest stability value in the automotive electronics field was 86.22%; and the highest stability value was 94.98% in the radio astronomy field. The stability of the address query and signal processing system combined with the AI sensor array in the time domain is in a balanced state. However, traditional address query and signal processing systems generally did not exceed 62%; the lowest was 36.69% in the field of radio astronomy, and the highest was 62.00% in terms of audio equipment which, overall, was very low. The stability of the system using traditional methods cannot be maintained in a balanced state and is unstable. In this case, in order to maintain the effectiveness of the data, an AI sensor array time-domain address query and signal processing system is suitable for application in various fields.

4.2 Timeliness

For humans, time is an abstract concept. People use it as a physical scale to measure the length of intervals between material motion processes or events. That is to say, time is a measure used to describe changes, and the speed of time is to some extent related to the data collected in various fields. This study compared the temporality between the time-

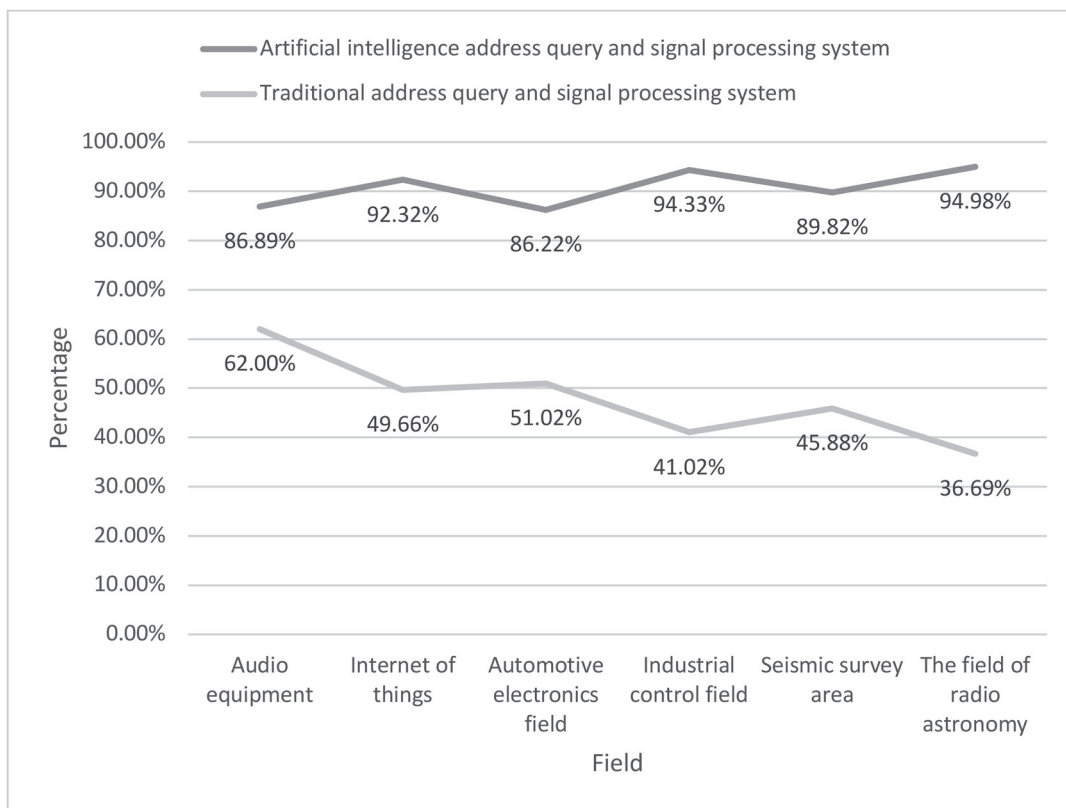


Figure 3 Comparison of the stability of the two systems.

domain address query and signal processing systems of AI sensor arrays and that of traditional address query and signal processing systems. The comparison results are shown in Figure 4.

Figure 4 shows the temporal control between AI address query and signal processing systems and traditional address query and signal processing systems. The longest time required to process data and obtain results in an AI address query and signal processing system was no more than 120 seconds (two minutes). The longest time used was 119 seconds in the field of seismic survey, and only 32 seconds in terms of audio equipment. Although the computational complexity was large, the system had sufficient capacity and technology to support it. However, traditional address query and signal processing systems required a longer computation time, 181 seconds in the field of radio astronomy; the minimum time required for audio devices was 74 seconds. With just this one-minute time difference, the traditional system may still be processing the data while the AI-assisted system has quickly come up with the results. This is not only a time difference; it also indicates that an AI-facilitated address query and signal processing system is faster.

4.3 Accuracy

Accuracy is crucial because when poor-quality data has produced unreliable or potentially harmful results, application systems in various fields are meaningless and require a lot of time and effort. If careful attention is not paid to the accuracy of the results, this can lead to errors in the analysis and the taking of a wrong direction. This study compared the accuracy

of time-domain address query and signal processing systems for AI sensor arrays with those of traditional address query and signal processing systems. The comparison results are shown in Figure 5.

Figure 5 shows the comparison of data accuracy using two methods. The accuracy rate in various fields where AI address query and signal processing systems were applied was generally over 90%, with the lowest being 90.89% in the industrial control field and the highest being 98.84% for audio devices, providing excellent accuracy for various fields. The accuracy of using traditional address query and signal processing systems in various fields was generally below 56%, with the lowest being 38% in the seismic survey field and the highest being 55.32% in the Internet of Things field. It can be seen that in intelligent mode, although the minimum was 90.89%, the data was also very accurate, which means that the highest-quality data can be used in various fields to obtain the most effective analysis.

4.4 Extensiveness

Extensiveness refers to the scope and breadth of events that occur. In this study, universality was considered to be the scope covered by different systems. When the scope and breadth of use are different, the impact is actually not the same. Therefore, a comparison was made between the temporal address query and signal processing systems of AI sensor arrays and traditional address query and signal processing systems to see if the influence of their universality can be determined. The comparison results are shown in Figure 6.

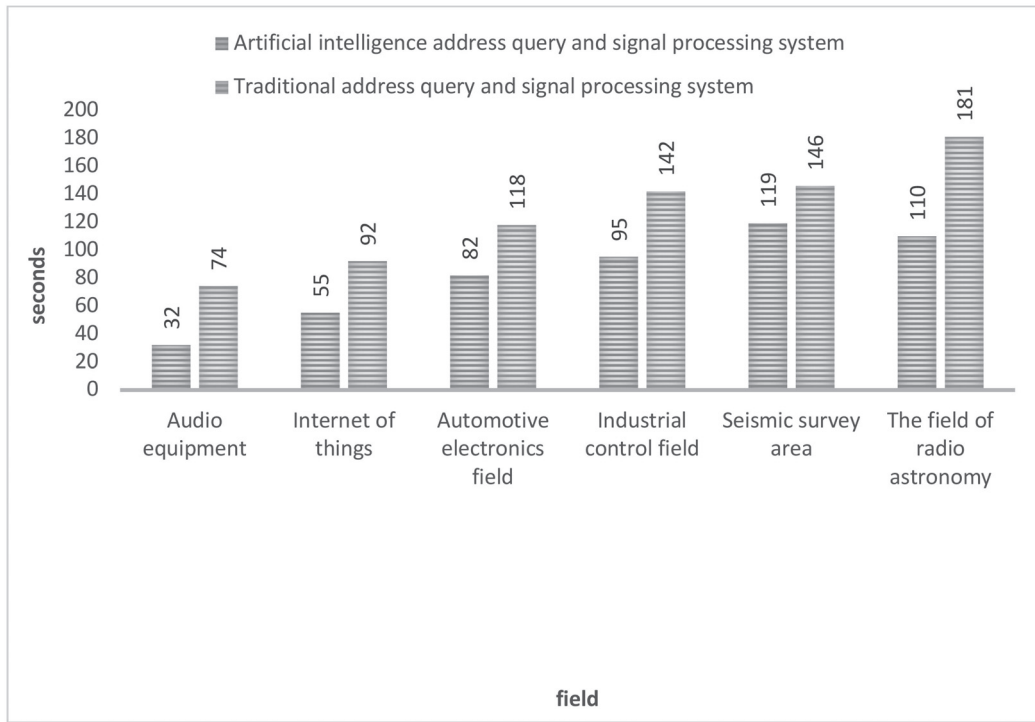


Figure 4 Comparison of the running time between the two systems.

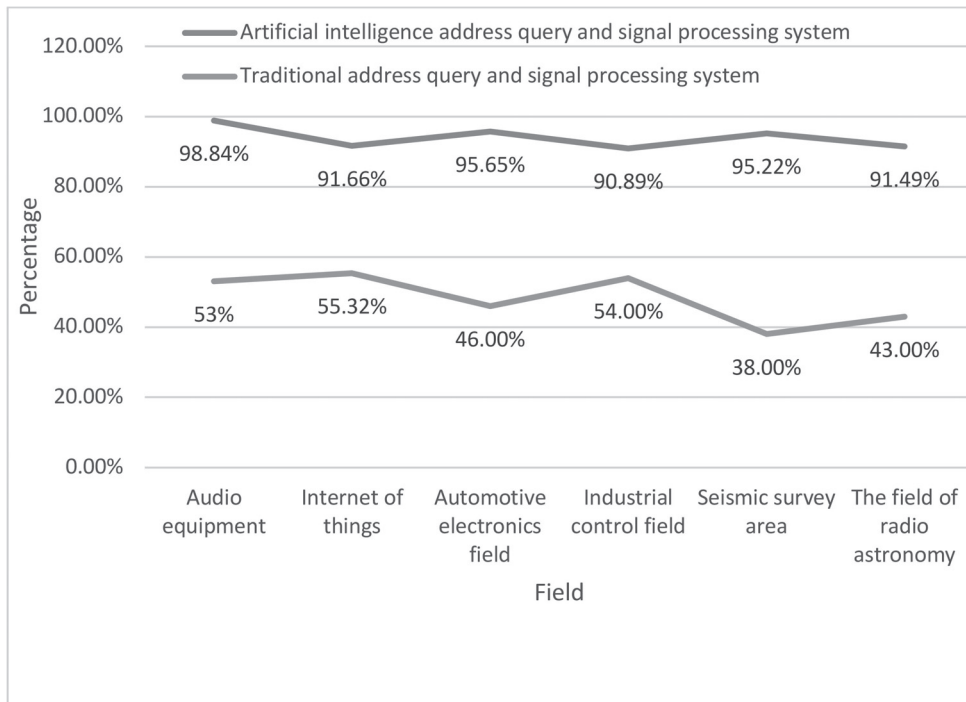


Figure 5 Comparison of the accuracy between the two systems.

Figure 6 enables a comparison to be made of the universality of the address query and signal processing systems of AI sensor arrays in the time domain and those of the traditional address query and signal processing systems. In Figure 6, it can be observed that the application of intelligent systems was more widespread, and they were in an increasing state no matter which field they were in; the maximum number of applications was 120, and the minimum was also 76. The application of traditional systems in various fields was

always unstable, with a maximum of 50 applications and a minimum of 29. Compared with traditional address query and signal processing systems, the number of applications of AI sensor array time-domain address query and signal processing systems was 51.8 more on average. Therefore, the use of AI sensor array time-domain address query and signal processing systems in various fields has a greater impact and better universality.

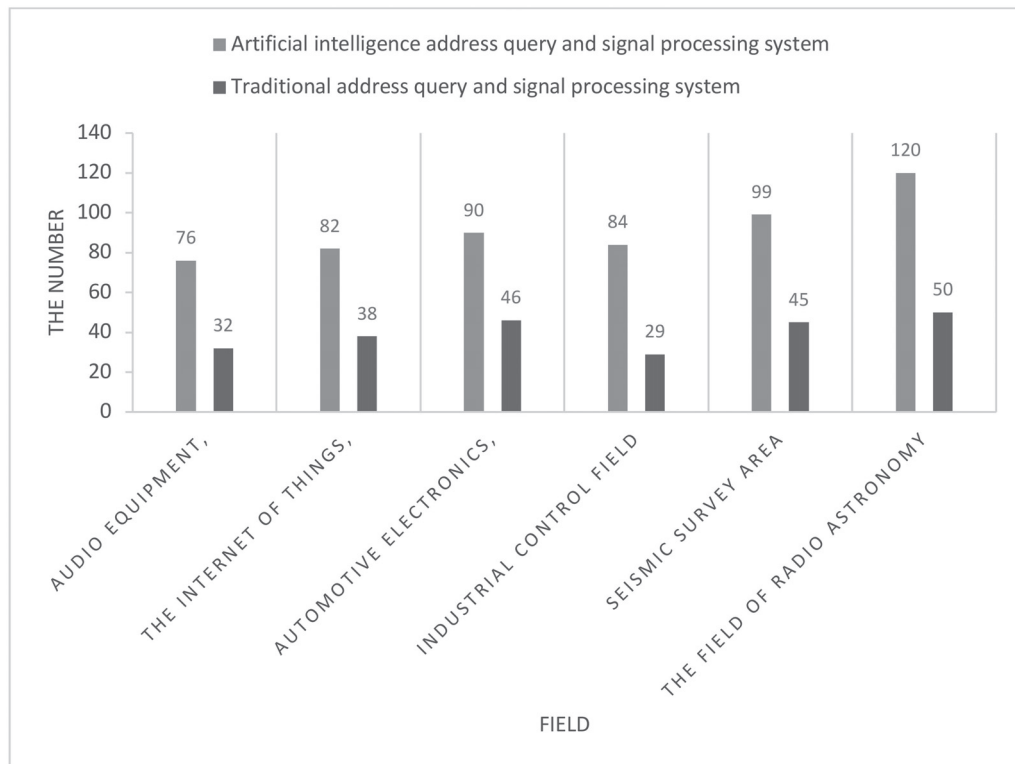


Figure 6 Generalized comparison of the two systems.

5. CONCLUSIONS

With the rapid development of address query and signal processing technology, the address signal environment encountered by various fields has become increasingly complex, and the diversity of forms has also led to an increase in selectivity. This study compared and analyzed the data in terms of four aspects of the time-domain address query and signal processing system of AI sensor arrays with traditional address query and signal processing systems, in order to understand the disadvantages of using traditional methods. This study used the MUSIC algorithm to analyze the inherent structure of these two problems from a geometric perspective. This study also combined AI sensor arrays with address query and signal processing systems to conduct research. The results showed that the intelligent array address query and signal processing system can solve the problems existing in traditional methods, and the algorithm used can greatly improve the resolution ability of the array antenna and relax the constraints on the array structure. It is of great significance for the research and development of both civilian and military equipment, and can further promote the advancement of this field of technology.

REFERENCES

1. Haeb-Umbach R, Watanabe S, Nakatani T. Speech processing for digital home assistants: Combining signal processing with deep-learning techniques. *IEEE Signal Processing Magazine*, 2019, 36(6): 111–124.
2. Zhong K, Zhou X, Huo J. Digital signal processing for short-reach optical communications: A review of current technologies and future trends. *Journal of Lightwave Technology*, 2018, 36(2): 377–400.
3. Mishra K V, Shankar M R B, Koivunen V. Toward millimeter-wave joint radar communications: A signal processing perspective. *IEEE Signal Processing Magazine*, 2019, 36(5): 100–114.
4. Liu F, Zhou L, Masouros C. Toward dual-functional radar-communication systems: Optimal waveform design. *IEEE Transactions on Signal Processing*, 2018, 66(16): 4264–4279.
5. Hu S, Rusek F, Edfors O. Beyond massive MIMO: The potential of data transmission with large intelligent surfaces. *IEEE Transactions on Signal Processing*, 2018, 66(10): 2746–2758.
6. Gao C, Yu L, Xu Y. Partial discharge localization inside transformer windings via fiber-optic acoustic sensor array. *IEEE Transactions on Power Delivery*, 2018, 34(4): 1251–1260.
7. Li W, Teng C, Sun Y. Sprayed, scalable, wearable, and portable NO₂ sensor array using fully flexible AgNPs-all-carbon nanostructures. *ACS Applied Materials & Interfaces*, 2018, 10(40): 34485–34493.
8. Li Z, Askim J R, Suslick K S. The optoelectronic nose: colorimetric and fluorometric sensor arrays. *Chemical Reviews*, 2018, 119(1): 231–292.
9. Huang Y C, Liu Y, Ma C. Sensitive pressure sensors based on conductive micro-structured air-gap gates and two-dimensional semiconductor transistors. *Nature Electronics*, 2020, 3(1): 59–69.
10. Gao C, Wang W, Song S. Localization of partial discharge in transformer oil using Fabry-Pérot optical fiber sensor array. *IEEE Transactions on Dielectrics and Electrical Insulation*, 2018, 25(6): 2279–2286.
11. Tan M, Wang C, Xue B. A novel deceptive jamming approach against frequency diverse array radar. *IEEE Sensors Journal*, 2020, 21(6): 8323–8332.
12. Ortega A, Frossard P, Kovacevic J. Graph signal processing: Overview, challenges, and applications. *Proceedings of the IEEE*, 2018, 106(5): 808–828.

13. Schmidt O T, Colonus T. Guide to spectral proper orthogonal decomposition. *AIAA Journal*, 2020, 58(3): 1023–1033.
14. Siddikov I, Sattarov K, Khujamatov H. Modeling and research of circuits of intelligent sensors and measurement systems with distributed parameters and values. *Chemical Technology, Control and Management*, 2018, 2018(3): 50–54.
15. Bao Q, Yuan S, Guo F. Transmitter beamforming and weighted image fusion-based multiple signal classification algorithm for corrosion monitoring. *Structural Health Monitoring*, 2019, 18(2): 621–634.
16. Qu, Shujuan. Design of Interface Display Optimization Algorithm for In-vehicle Interaction System Based on Artificial Intelligence. *Engineering Intelligent Systems*, 2024, 32(5): 465–475.
17. Wei, Jie. Agile Supply Chain Management Collaboration Based on Artificial Intelligence Traceability System. *Engineering Intelligent Systems*, 2024,32(5): 401–410.
18. Ma, Xiaomeng, Song, Yi, Hu, Bin. The Mobile Crowdsourcing-Based Turnover Behavior of Courier Under Community Group-buying Scenario influenced by Interaction and Service Quality. *Engineering Intelligent Systems*, 2024, 32(4), 359–372.



Haixia Guo, born in 1976, graduated from Harbin Normal University in 1998 with a degree in science. She graduated from Harbin Normal University in 2007 with a Master's degree in Engineering. She is currently working in the Department of E-commerce at the School of Computer and Mathematics, Harbin Finance University. Research interests include graphic and image processing, artificial intelligence, etc.
E-mail: 15822158548@163.com