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Design of Power Communication Data Network Management System and Implementation of Data Acquisition Module

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Abstract: The power communication network is a separate network from the power grid whose primary purpose is to ensure the power grid's safe operation. This paper expounds the composition of the comprehensive network management architecture of the power communication data network and the implementation of the data acquisition module in the network management system through theoretical analysis, for the reference of relevant personnel, in order to better promote the collection of power grid communication network data.

Keywords: Electric power communication; Network management system design; Data acquisition

Publication date: November 2021; ***Online publication:*** November 30, 2021

1. Introduction

Power communication network plays an important role in the operation of power grid and is also an important part of the national power grid economy. Power communication data network management covers a wide range of business. It is necessary to continuously strengthen the management of power communication data network management system in order to better promote the operation of power communication data network management system. Therefore, the design of data module in power communication data network management system is of great significance for the development of power communication data network management system [1]. According to the requirements of business, function and data of power communication data network management system, it is imperative to improve the data module. The data module can realize the alarm monitoring of power data and the fault treatment of power data. Through the data module, the flow analysis and configuration audit of power grid communication data can be realized, and the real-time inspection and maintenance of power grid communication can ensure the safe operation of power grid communication network; The data module can also collect dynamic resource data, collect alarm data and sort out logs, reflect the data situation of the current power communication network through the analysis of performance data [2], and ensure the safe implementation and development of power communication services. In addition, it can also meet the functional records of power communication data network management, and ensure the safe operation of power grid communication data network management system.

2. Integrated network management architecture of power communication data network

At present, the integrated network management architecture of power communication data network mainly includes acquisition adaptation layer, application layer, information representation layer and network element layer. The specific architecture is shown in **Figure 1**.

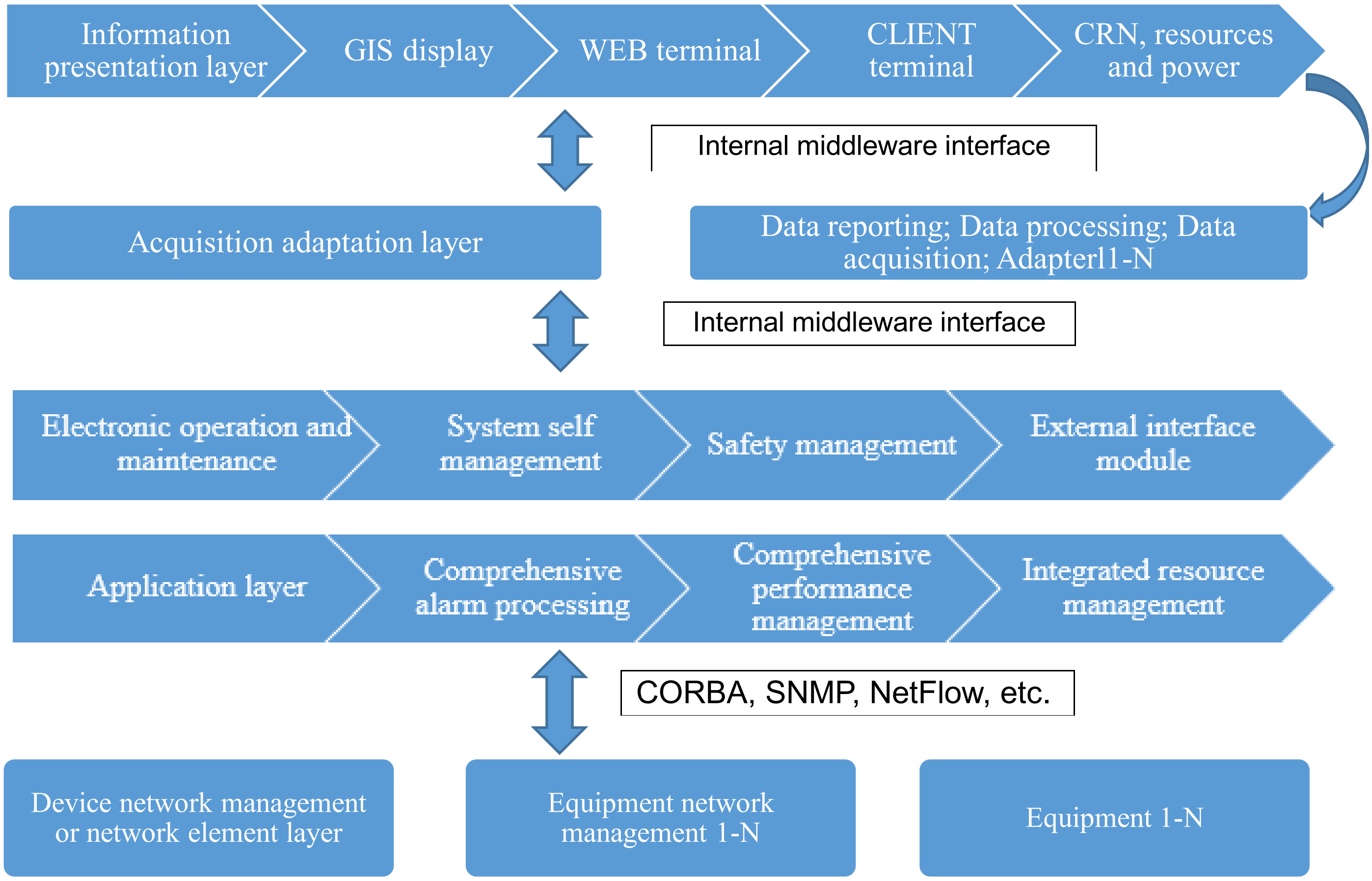

Figure 1. Design framework of power communication data network management system

(1) Device network management or network element layer: The required access interfaces of managed devices and unmanaged devices are different. The access interfaces of unmanaged devices are provided by the network element layer, which can be accessed by accessing the interfaces provided by the network element layer, so as to obtain the data information required by the device; The access interface of the managed equipment is provided by the equipment network management, including the private interface, which can access the data information, so as to realize the data sharing and real-time information exchange of all access equipment.

(2) Acquisition adaptation layer: Among the current popular interface protocols, Common Object Request Broker Architecture (CORBA), Simple Network Management Protocol (SNMP) and NetFlow are widely used. At present, the interface protocols adopted by the equipment connected to the power communication network are different. Therefore, in order to avoid inaccessibility, an acquisition adapter layer needs to be set in the power communication network management to connect the acquisition adapter, in this way, each type of network management equipment can be accessed. Different adapters correspond to different network management systems and different network element types.

(3) Application layer: The main function of this level is to realize the interaction of functions, including the real-time sharing of data information, data information processing, data information analysis of each network element interface and north interface. In this level, it can realize the warning processing of data information and connect each functional module in the power communication network management system. It is the main information interaction layer. In order to better realize

the role transformation, through the special interface function, realize the interaction of power communication network management system resources and support various electronic equipment, so that power communication network management system can operate stable.

(4) Information presentation layer: The main function of this layer is to display relevant information to users, realize the visualization of various data information, and facilitate users to intuitively understand the contents of various data information. The superior docking layer of the information presentation layer is the application layer and only connects with the application layer. The content of information data is displayed to the client in browser mode and client server mode.

3. Realization of data acquisition function of power communication data network management system

3.1. Processing of alarm data

Configuration and alarm data constitute the data type collected, in which the configuration data can provide the required data to the resource management subsystem, so as to realize network management; Alarm is an abnormal prompt message sent by power communication network equipment during operation, which is sent to operation and maintenance personnel through work order or short message to accurately judge the fault location, type and severity, and carry out targeted maintenance. When implementing alarm data processing, the number of network equipment alarms shall be considered to make the system design of data network management highly scalable and flexible, meet the correct technical selection, and make the interface interactive and maintainable [3].

3.2. Collection of performance data

The realization of module functions includes initialization operation, data acquisition, remote control and etc. In order to effectively realize performance data acquisition, it is necessary to pay attention to remote control and do a good job in each initial operation, which requires the assistance of predefined interface protocol, and then carry out accurate operation through the required adaptation function. In addition, the designed task table needs to be imported to allow remote instructions to control subsequent overload operations, and then change the configuration accurately and quickly to meet the operation needs. In addition, when collecting various data, there must be a background description to effectively collect performance related data, and then obtain extremely accurate new performance data through scientific incremental analysis and carry out detailed operations.

3.3. Collection and control of configuration data

The collection and control of configuration data shall first realize the remote function, establish the basic configuration and operation and maintenance debugging command library of various stations, and complete the configuration and commissioning of new stations through command call. After a series of initialization operations, carry out daily monitoring and data collection for field equipment and services at all levels designated in the background [4]. During operation, the acquisition and control functions shall be realized through the transmission function interface according to the specific session protocol.

3.4. Realization of acquisition control function

Data acquisition and control are based on alarm information and combined with acquisition business logic for exception management and storage operation. The collection of alarm data covers the remote control link. It is also necessary to carry out corresponding data collection and complete the scientific call of instructions required by the predefined interface. The acquisition control will carry out subsequent operations through the start-up instructions in combination with the actual situation. In the specific acquisition process, it shall be carried out according to the specific subnet protocol. In the process of operation, the differences of subnet acquisition interfaces should be considered, so as to call the function interface in advance and realize the function to a great extent [5].

3.5. Protocol adaptation execution

The implementation of protocol adaptation needs the assistance of control framework to scientifically and comprehensively analyze the acquisition instructions. After the session is established, the obtained information should be converted accordingly, for example, specify a format, and then provide an interface that satisfies its return requirements. Generally speaking, the operation of alarm collection can be triggered through the collection control framework, then deeply analyze the manufacturer’s protocol, complete the protocol adaptation operation, and then realize it through the callback interface. Due to the system can receive alarm information in various environments to a great extent, it can bring practical and effective guarantee to the whole operating system through scientific and automatic processing. If the system cannot operate anymore, for example, it is in a resting state, we can use destroy callback method to quickly clear all the original information of the interface. For NetFlow protocol, it does not need polling, so it is easy to handle [6]. After the main program is started, NetFlow protocol can be automatically collected. At the same time, the program will collect the received data and input it into the database, convert it into alarm data, transmit it to the upper layer and process it. SNMP trap will send trap packets without polling. It can accurately analyze the alarm information and complete the write operation of the database. For SNMP protocol, the SNMP interface in the acquisition module will perform SNMP get operation, and the agent will quickly package the extracted effective data, convert it into external format, then perform the encapsulation operation, and send it to the manager in the form of SNMP package to realize the implementation of protocol adaptation.

4. Summary

To sum up, the current power communication gateway system mainly includes four technical support layers, namely, acquisition adaptation layer, application layer, information representation layer and network element layer. Through the elaboration and analysis of the architecture, the implementation of data acquisition module is proposed. And through the collection of alarm data, performance data and configuration data, further realize the acquisition control function and protocol adaptation execution function, so as to complete the realization of the data acquisition module of power communication data network.

Disclosure statement

The author declares no conflict of interest.

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Vibration Test Measures for Pump Fault Diagnosis

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Abstract: The vibration measuring standard for compound machinery utilized in modern industrial production will be employed for the application of detecting technologies. The vibration intensity can be obtained by selecting the detecting method to obtain the speed of mechanical vibration, and technicians can examine whether the vibrating machinery is in a proper functioning state based on the value of vibration intensity, allowing for thorough fault diagnosis. In order to provide useful diagnosis ideas for technicians, this study examines the measurement of mechanical vibration and investigates the calculating method of mechanical vibration intensity.

Keywords: Vibration test; Pump; Calculation; Diagnosis

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1. Introduction

Pumps used in industrial production are mainly used to transport raw materials, including liquid materials such as water, oil and emulsion, or to transport some suspended solids. At present, most of the pump machinery used in domestic industrial production are imported equipment, and the fault monitoring and fault diagnosis of pumps need to be completed by domestic technicians. Therefore, technicians should better understand the fault detection mode of the pump, clarify the vibration test standard of the pump, and make accurate judgment on the fault of pump equipment. Taking the test of bearing and pressure end of F-1300 ordinary drilling pump as an example, it can illustrate the fault diagnosis of pump equipment.

2. Pump mechanical vibration test

2.1. Speed test principle

According to the analysis of physical properties during the measurement of pump equipment, the test methods of vibration speed can be mainly divided into three kinds, including mechanical measurement method, electrical measurement method and optical measurement method. In this test, the vibration speed is controlled by means of acceleration sensor, the acceleration signal is A / D converted, filtered into DC signal, and then filtered to meet certain requirements. Technicians can use digital frequency domain filtering. The advantage of this approach is that it is relatively simple, and the calculation speed is relatively fast, the control accuracy of the filtering frequency band is relatively high, it has strong flexibility, and does not produce time shift effects, The actual generated data has gone through the process of MATLAB numerical processing. The process is to pass the acceleration signal a, obtain high-pass filtering, and send out the speed signal. After the trend term is removed by the polynomial fitting data, the usable speed signal is obtained. This is the speed test principal process [1].

2.2. Arrange the pump vibration speed tester

As shown in **Figure 1** and **Figure 2**, it is the layout mode of pump bearing and hydraulic end vibration test of F-1300 ordinary drilling equipment in the test.

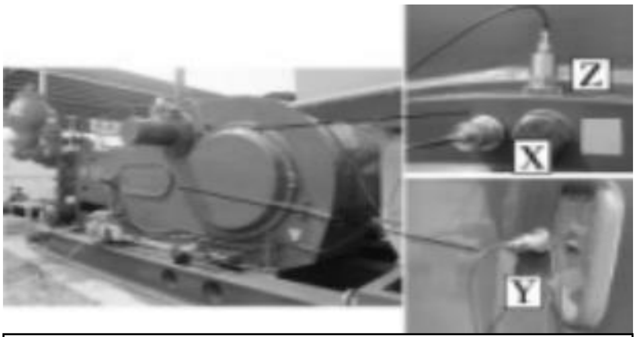

Figure 1. Schematic diagram of test instrument at pump bearing (Reference)

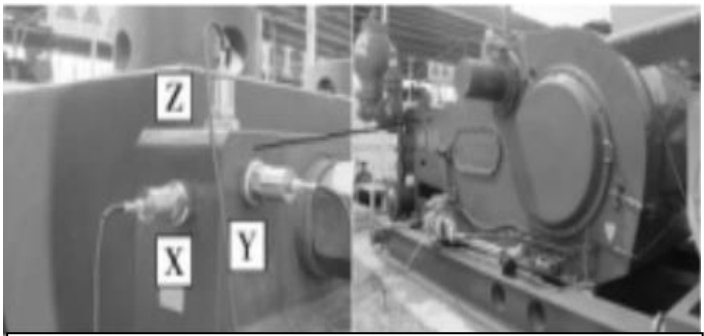

Figure 2. Schematic diagram of test instrument at hydraulic end of pump (Reference)

2.3. Collect vibration signal

From obtaining the measured signal, it is sent to the piezoelectric acceleration sensor, then input to the KD5018 charge amplifier, recorded to the NI9205 data acquisition card, and the discrete digital signal is given through the notebook [2].

2.4. Process vibration signal

Technicians can use MATLAB to collect data. Different processing speeds can be obtained with the change of time. For example, the change of X and Y points shown in **Figure 3** and **Figure 4** can obtain the integral speed graph.

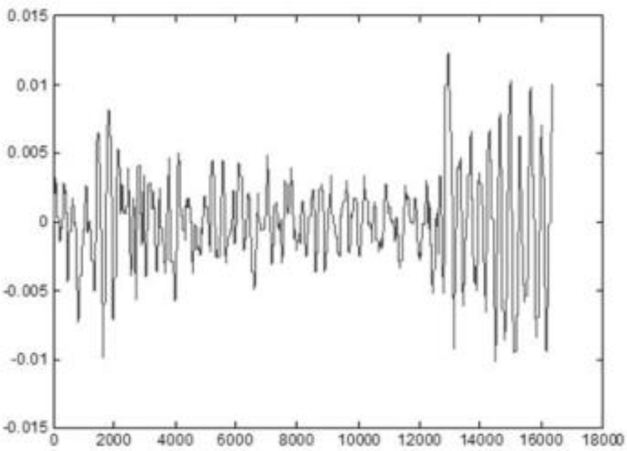

Figure 3. Calculation results of frequency domain integration of X-direction detrended term (Reference)

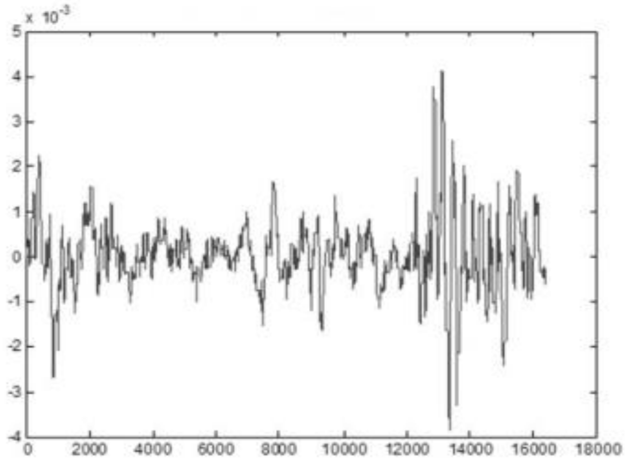

Figure 4. Calculation results of frequency domain integration of Y-direction detrended term (Reference)

3. Pump mechanical vibration intensity calculation

The vibration intensity of pump machinery can be defined as the frequency range, which is the root mean square value of vibration speed of 10-1000Hz. For example, the vibration signal is v(t), the calculation time is T, the vibration intensity is (1)v = $\sqrt{\frac{1}{T}\int_{o}^{T} v2(t)dt}$, the square root value can be taken within the range of signal v(t) in (0, t), the discrete vibration velocity signal at point n is v(n), and the calculation formula can also be written as (2) $V = \sqrt{\frac{1}{N}\sum_{n}^{N-1} v2(n)}$. For the standard of strong vibration, refer to the contents in the

"Method for Measuring and rating vibration of Reciprocating Machines" issued by relevant national departments, that is, the contents shown in **Table 1**.

Table 1. "Reciprocating Machinery Vibration Measurement and Rating Methods" issued by relevant national departments (Reference)

Vibration intensity		**Vibration quality**			
Range	**Effective value of speed / mm / S**	**Class I**	**Class II**	**Class III**	**Class IV**
0.071	-				
0.11	0.11	Excellent			
0.18	0.18		Excellent		
0.28	0.28			Excellent	
0.45	0.45				Excellent
0.71	0.71				
1.12	1.12	Good			
1.8	1.8		Good		
2.8	2.8	Allowed		Good	
4.5	4.5		Allowed		Good
7.1	7.1	Not allowed		Allowed	
11.2	11.2		Not allowed		Allowed
18	18			Not allowed	
28	28				Not allowed
45	45				
71	71				

The vibration intensity can be calculated according to the principle of 36 by referring to (1) and (2) in the MATLAB formula. The integral calculation method of detrended term is adopted to calculate the direction intensity of X and Y, and the corresponding mean value and standard deviation are given. In the bearing, the calculation results can be reflected in **Table 2** and **Table 3**. And the calculation results of the hydraulic end of pump mechanical equipment can be reflected in **Table 4** and **Table 5**. The values are all derived from the vibration intensity in this direction, the vibration intensity in the X direction is 3.1928mm/s, the vibration intensity in the Y direction is 0.8202mm/s, and the vibration intensity in the X direction is the largest. Petroleum mechanical equipment belongs to class IV, and the evaluation of technical conditions is good. The value is the vibration intensity in this direction, the vibration intensity in the X direction is 0.9652mm/s, the vibration intensity in the Y direction is 1.2771mm/s, and the vibration intensity in the Y direction is the largest. This kind of machinery is classified as class IV. Therefore, the evaluation of its technical condition is excellent [3].

4. Common faults of drilling pump and location of test points

During the operation of the drilling pump, irregular vibration problems often occur. Some vibration signals are generated by the operation of the machine, and some vibration may also be caused by abnormal parts in the pump. If the drilling pump fails and the mechanical equipment cannot operate normally, the vibration signals generated at different positions will have different reactions in the equipment. Therefore, technicians should find accurate test points in vibration test and judge which form vibration belongs to. For example, judge whether the drilling pump belongs to the vibration generated under normal working conditions, judge whether the drilling pump cycle has regular vibration, judge whether the vibration is caused by defects in design and processing, whether the vibration belongs to irregular fault problems, and whether it is caused by mechanical resonance around the mine. In practice, it can be seen that the vibration of most pump equipment is related to the regular vibration caused by the periodic cycle, which may be because the vibration signals caused by the surrounding machines are considered to be the same signals based on the filtering of clutter signals. If it is the fault diagnosis of pump equipment, it is not a regular signal, so it is easy to identify, technical personnel can also locate it accurately, which is more beneficial to the overall mechanical fault judgment [4].

The hydraulic end of the drilling pump includes components such as discharge valve and suction valve. If these parts are damaged, they will affect the vibration of the faulty equipment. For example, the piston in the pump equipment is mainly in the form of periodic movement, and the friction generated in the movement will form impact wear. In the process of downward reciprocating movement, the parts may fail. Among them, the piston rod and the intermediate rod are connected by clamps, so technicians need to monitor it in real time. There may be vibration impact between the valve body and the valve seat due to operation, but the main causes of these problems are caused by the failure of the pump valve. Therefore, the abnormal vibration of pump equipment components will be transmitted to the valve box. If the power end of the drilling pump equipment is faulty, it may be because the crosshead of the reciprocating pump is subjected to a huge impact force during operation, and the lubrication effect of the bearing part is not ideal, so the wear problem will be exacerbated, and the vibration frequency will be expanded, resulting in greater friction between gears, and then the gear may fail in operation, and the abnormal vibration of these components will be very obvious in the body. The technicians selected the appropriate sampling frequency according to the sampling theorem. Referring to the normal working condition of the drilling pump, the normal vibration frequency is within 5000Hz. Therefore, if the sampling frequency is greater than this value, it can indicate that the vibration is abnormal.

Table 2. Vibration intensity at pump bearings (Reference)

Number of data groups	**1**			**2**			**3**			**4**			**5**		
Measurement direction	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
Vibration intensity	3.3803	0.7728	1.2658	3.1655	0.77776	1.1821	2.9811	0.8685	1.4936	3.4786	0.7917	1.2792	2.9583	0.8904	1.3224

Table 3. Mean and standard deviation of vibration intensity at pump bearings (Reference)

X		**Y**		**Z**	
Mean value	Standard deviation	Mean value	Standard deviation	Mean value	Standard deviation
3.1928	0.0543	0.8202	0.0030	1.3086	0.0133

Table 4. Vibration intensity of hydraulic end of pump (Reference)

Number of data groups	1			2			3			4			5		
Measurement direction	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
Vibration intensity	0.8786	1.3181	1.1578	1.0033	1.2323	1.2420	1.1554	1.2298	1.1251	0.8673	1.3432	1.2636	0.9213	1.2621	0.9990

Table 5. Mean and standard deviation of vibration intensity of hydraulic end of pump (Reference)

X		Y		Z	
Mean value	Standard deviation	Mean value	Standard deviation	Mean value	Standard deviation
0.9652	0.0142	1.2771	0.0026	1.1575	0.0111

5. Conclusion

In industrial production, pump equipment collects signals through vibration, and the vibration intensity can be obtained by processing data with MATLAB. Then, the working condition of pump equipment can be evaluated according to relevant standards, including four grades: excellent, good, general and poor. Technicians can give evaluation opinions according to the results. If the evaluation result is not good, it can be stopped for rectification. If the evaluation result is good, production can be arranged normally. In the process of calculating vibration intensity from spectrum method, technicians can relax the requirements for vibration signal, provide convenience for calculating frequency, help to enhance the flexibility and applicability of calculation, reduce the influence of signal randomness and make the calculation result more stable.

Disclosure statement

The author declares no conflict of interest.

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Research on Virtual Reality 3D Exhibition Hall based on the Smart Campus of Geely University

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Abstract: With the support of Geely college, this study aims to solve the problem that teachers and students' works cannot be displayed under special circumstances. Using this set of applications breaks through many conditions such as time and region, shows learning style to teachers and students and the outside world, and provides a way for knowledge dissemination and sharing.

Keywords: UE4; 3D exhibition hall; Blueprint

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1. Introduction

Art and engineering class closing exhibition and graduation work exhibition in colleges and universities have always been an important form of teaching in colleges and universities, but the sudden epidemic makes the work exhibition under the front line unable to be held normally. Then online exhibition becomes an effective solution. As an advanced technical means, virtual exhibition hall greatly reduces the consumption of resources and energy, weakens the dependence on region and capital, truly realizes the never-ending exhibition hall platform, and permanently retains the excellent works of teachers and students and data access. This technology is not limited to professionals, as long as it can be displayed or the contents of the exhibition can use this technology. The application breaks through the restrictions of time, place and platform, and can use mobile phones, PCs, VR and other devices to show more people the style of teachers and students. Promote the dissemination of culture and education and make up for regional restrictions.

Through the research of this subject, the problem that the works of teachers and students cannot be displayed under special circumstances is solved, so that the exhibition hall breaks through many conditions such as time and region, can display to more teachers and students and the outside world, and speed up the dissemination, exchange and sharing of knowledge through network means. Moreover, the platform has the characteristics of autonomy, can be designed and adjusted flexibly, and is not limited by the third party.

2. Development tool

In the model part involved in the application, SketchUp, 3dmax and Maya are used to complete the design and production of venues and models, Photoshop is used to complete the design and production of maps, import the three-dimensional model to UE4, complete the production of light, PBR material [1] and dynamic simulation in UE4, and write interactive scripts through visual C++ and blueprint [2] to simulate the first person vision. The system structure is shown in **Figure 1**.

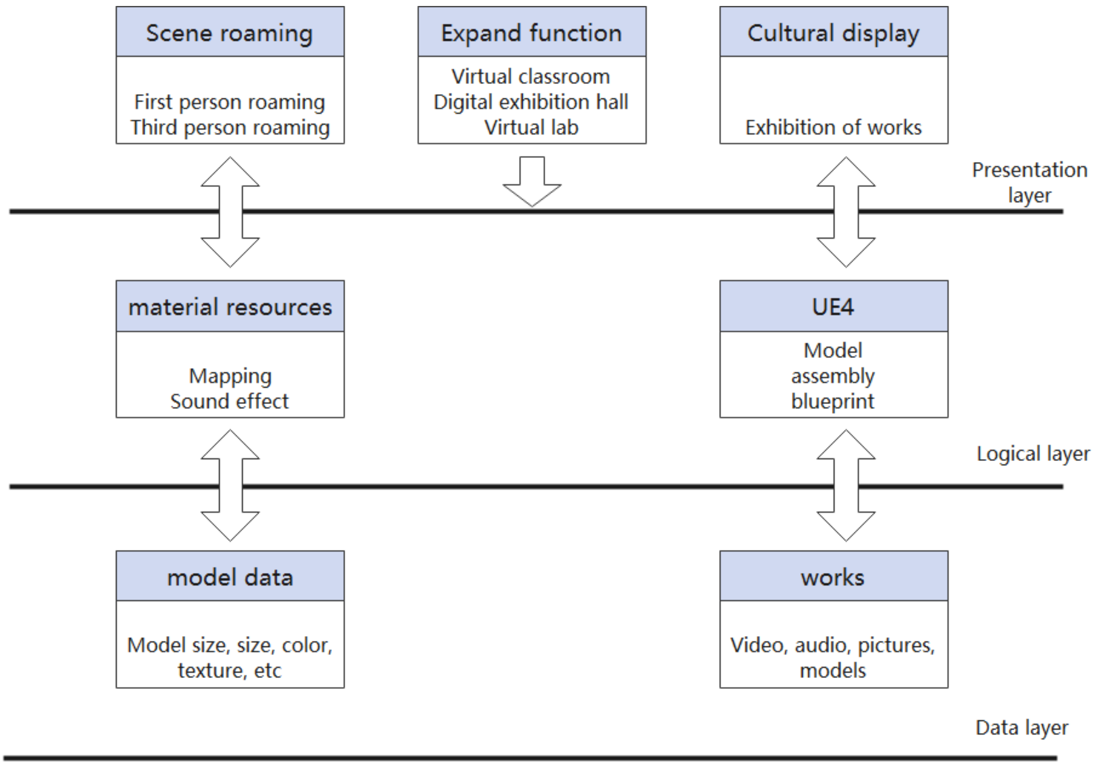

Figure 1. The system structures

3. Material preparation collection

At the beginning of the production, we collected a lot of information about the three-dimensional virtual exhibition hall, compared the current offline and online virtual three-dimensional exhibition halls, and finally determined the exhibition form and exhibit type of each part of the exhibition hall. Since the school is in the construction stage and there is no physical exhibition hall, we designed the three-dimensional exhibition hall ourselves. The types of exhibits include sculpture, plane products, environmental art, automobile, etc.

4. Model processing and import

Due to certain requirements on the number of faces and specifications of the model, Therefore, virtual geometry technology [3] is used all basic 3D models are made by Maya and 3DMAX, and then imported into UE4 engine by Max or Maya through the plug-in officially provided by UE4. The high modulus part is made in UE4, and the map is only given basic materials in Maya and 3DMAX. After importing UE4, use the BPR material editor and re edit all materials based on the HD materials officially provided by UE4.

5. Lights and materials

As the scene is a closed design, in order to simulate the real light as much as possible, the scene light production adopts the way of light array. Considering the high requirements of GPU light on computer, the CPU mode is used to build the light in the whole scene.

The models of the whole three-dimensional exhibition hall have many different categories, so it takes a long time to make the materials. The paint materials of cars are designed again based on the paint material effect on the official website. The materials of other parts are designed by ourselves.

6. Blueprint interaction

The interactive script of the scene is encapsulated in the function for easy calling. This design uses the first persons' perspective, which can give a good sense of substitution. The car interaction part is designed with light switch, paint switch and independent UI control panel. When browsing the scene, you can call out the UI panel according to the needs of "tourists."

The product part is displayed in a dynamic way. When the "tourist" approaches the product, the product introduction and description are dynamically realized in the form of HUD above the booth facing the "tourist." After leaving the booth, the HUD automatically disappears.

The animated character works in the exhibition hall are displayed in a dynamic trigger way. When the "visitors" approaches the animated character, the character makes some specific actions, and the action stops after leaving the booth. This makes the animated character "come alive" and more visually expressive and infectious. A media player is added to the in the exhibition hall, which can be turned on according to the needs of "visitors" to play videos.

7. Combining content release with smart campus

Due to the problems of time and hardware equipment, this set of applications is only used on the windows platform. You can provide download links on the school's official website and experience freely after downloading locally, or set up a three-dimensional exhibition hall server in the future to provide client download for network experience, and constantly update and iterate for permanent use.

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Research on the Application of Deep Learning in Artificial Intelligence Courses

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Abstract: With the in-depth reform of education, taking students as the center, letting students master the basic knowledge of the theory, but also training students' practical skills, is an important goal of the current artificial intelligence curriculum teaching reform. As a new learning method, deep learning is applied to the teaching of artificial intelligence courses, which can not only give play to students' subjective initiative, but also improve the efficiency of students' classroom learning. In order to explore the specific application of deep learning in the teaching of artificial intelligence courses, this article analyzes the key points of the application of deep learning in artificial intelligence courses. In addition, further explores the application strategies of deep learning in artificial intelligence courses. As it aims to provide some useful references to improve the actual efficiency of artificial intelligence course teaching.

Keywords: Deep learning; Artificial intelligence courses; Application strategies

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1. Introduction

Compared with shallow learning, in the deep learning mode, students' learning initiative and enthusiasm can be brought into full play, and they can also help students build a systematic knowledge system, which is more helpful for students to understand the theoretical knowledge of artificial intelligence courses and corresponding practical applications. Under the national education policy environment that promotes quality education and focuses on talent training, applying deep learning to artificial intelligence curriculum teaching is an important means to meet the requirements of quality education reform and promote the realization of talent training goals. For this reason, when teachers are teaching artificial intelligence courses, it is necessary to have a deep understanding of deep learning methods and apply them scientifically to classroom teaching. From teaching concepts to learning goals, to classroom models and teaching environments, deep learning is applied in an all-round way. To improve the teaching quality of artificial intelligence courses. Based on this, this article analyzes and explores the application strategies of deep learning in artificial intelligence courses with positive practical significance.

2. Application points of deep learning in artificial intelligence courses

2.1. Based on understanding

Under the shallow learning mode, students are relatively passive in learning. Normally, teachers will tell theoretical knowledge on the stage, while students will be more passive in accepting knowledge taught by teachers. In this learning process, most students use the traditional learning method, that is, rote memorization, and only a small number of students will memorize on the basis of understanding. In this learning environment, although students understand more theoretical knowledge, their ability to apply knowledge to practice is not high. In the deep learning mode, students turn passive learning into active learning. Specifically, on the basis of existing curriculum resources, in addition to imparting basic theoretical knowledge, teachers can guide students to correctly and scientifically understand and master knowledge, which is also an important content of artificial intelligence curriculum teaching under the application of deep learning. Based on understanding, in short, it is to let students abandon the past learning methods of rote memorization, starting from the perspective of understanding, for example, what is the basic connotation? What does the actual application operation look like? Only with a thorough understanding of knowledge can we better grasp knowledge.

2.2. Build a system of knowledge system

Constructing a systematic knowledge system refers to combining all the knowledge points together on the basis of understanding and mastering the theoretical knowledge of classroom learning, combining the deep connotation of knowledge, summarizing all the knowledge points, and constructing an overall knowledge framework. With the in-depth reform of quality education, the state is paying more and more attention to educational innovation and development [1]. In addition to requiring school teachers to cultivate students' basic literacy, it is also necessary to improve students' practical application ability and promote students' comprehensive development. In order to cultivate students' comprehensive literacy, teachers must not only adopt correct teaching methods to help students master theoretical knowledge, but also allow students to learn to apply theoretical knowledge to solve practical problems. In order to achieve this teaching goal, teachers must apply the deep learning model in depth, first let students briefly understand the knowledge points of artificial intelligence classroom teaching, and then let students understand the knowledge points and master them in a guiding way. On this basis, teachers allow students to try to establish a knowledge framework for students to understand the important and difficult knowledge in artificial intelligence courses from a holistic perspective.

2.3. Transfer and use of knowledge

Different from shallow learning, the main purpose of deep learning is to let students know how to use knowledge flexibly in different situations and transform knowledge into practical skills. In the past shallow learning mode, the classroom teaching method is still relatively traditional. Students passively accept knowledge, and most of the time they use rote memorization to acquire knowledge. Although this has certain benefits for students to keep in mind the knowledge points, the key to knowledge learning is to be able to understand it and use it. It is based on this point that the students' understanding of knowledge is not thorough enough. Although they have completed the accumulation of knowledge, students do not fully understand the deep connotation of the relevant knowledge points of artificial intelligence courses. Naturally, the practical application of knowledge is relatively weak, which is inconsistent with the country's requirements for cultivating compound talents. For this reason, when teachers apply the deep learning model in artificial intelligence classroom teaching, in addition to helping students understand key and difficult knowledge, they should also guide students to learn the advancement and application of knowledge. Only in this way can we effectively promote the realization of education goals.

2.4. Focus on student experience

Paying attention to student experience is one of the main points in the application of deep learning in artificial intelligence course teaching. It emphasizes that students are the main body first, and then through the construction of corresponding learning situations, students can participate in learning in an experiential way. This will not make students feel boring in the classroom, but can also stimulate students' interest in learning and mobilize students' learning initiative, which can be said to be an important content of the innovative development of artificial intelligence classroom teaching. At present, as the education system continues to innovate and improve, school teachers have begun to use new teaching concepts, but because they are deeply influenced by traditional teaching models, they still integrate traditional teaching methods most of the time. Students passively participate in learning activities under the guidance of teachers [2]. Although it is different from the past cramming-style teaching, the focus of teaching is still to impart knowledge and does not pay attention to student experience, so it often fails to achieve good teaching results. For this reason, teachers should pay attention to the learning experience when applying the deep learning model in artificial intelligence classroom teaching, so that students can gain knowledge and understand knowledge in the experience, and improve their ability to understand knowledge.

3. Application strategies of deep learning in artificial intelligence courses

3.1. Implement scientific teaching concepts with student experience as the core

In order to apply the deep learning model to the teaching of artificial intelligence courses, teachers should take student experience as the core and thoroughly implement scientific teaching concepts. By clarifying the specific application methods and approaches of the deep learning model in the teaching of artificial intelligence courses, combined with the basic connotation of deep learning, perfecting teaching goals, choosing appropriate teaching methods, better carrying out artificial intelligence classroom teaching activities, and improving teaching efficiency. First, focus on student experience. The main goal of deep learning is to cultivate students' cognitive and creative abilities. Therefore, teachers must fully mobilize students' learning enthusiasm and initiative in the classroom, which depends on the learning environment and learning methods created by the teacher. By focusing on student experience, choosing appropriate teaching methods and creating a corresponding learning environment, focus on student experience and at the same time give play to the teacher's own guiding role. Second, teachers must implement scientific teaching concepts. With the in-depth reform of education, new educational concepts have gradually penetrated into the education system, and have gradually received national attention and attention. As a trainer of talents in the field of artificial intelligence, teachers should closely follow the pace of development of the times and implement new educational concepts, such as the teaching concept of "leading-subject integration [3]." In other words, on the premise of taking students' self-experience as the core, teachers first transfer knowledge to students, and then let students explore knowledge and solve problems autonomously through experience.

3.2. Develop deep learning goals based on curriculum standards

Students' deep learning ability is gradually developed through a series of learning processes on the basis of a clear deep learning goal. Therefore, teachers should be aware of the importance of in-depth learning goals, and combine the curriculum standards to formulate in-depth learning goals suitable for students' current learning conditions. Deep learning aims to develop students' analytical and creative abilities, and further promote the improvement of students' comprehensive literacy. In order to effectively achieve this goal, when designing teaching goals, teachers should first start from the student's perspective and understand the knowledge and experience they have in the cognitive structure of students. Based on the requirements of artificial intelligence curriculum standards and students' existing knowledge background, implement the design of class hours or unit teaching goals, and then develop deep learning goals for the fundamental purpose of promoting students' thinking, analysis, and creativity [4]. Teachers must not only ensure that the goal of deep learning can effectively promote the cultivation of students' comprehensive quality, but also ensure that the value of the knowledge of artificial intelligence courses can be fully reflected. For example, first understanding the relevant knowledge points of the artificial intelligence course, determine the initial understanding, and then the students personally explore, and finally the teacher will guide the students to summarize and summarize, and improve the students' analytical ability.

3.3. Establish a deep learning environment based on intelligent means

As the country pays more and more attention to the informatization of education, the establishment of a deep learning environment based on intelligent means is an important part of the reform and innovation of artificial intelligence classroom teaching. For this reason, when constructing a deep learning environment, teachers should create a corresponding deep learning environment by using multimedia teaching methods according to the actual student situation of the students and the content of the course knowledge. For example, the establishment of a deep learning environment based on the context of the problem. First of all, teachers are familiar with the knowledge points related to artificial intelligence in this classroom teaching, understand the basic knowledge, important and difficult knowledge points, and ask questions. Secondly, before starting the class, the teacher uses the multimedia to ask the students to briefly understand the knowledge points to be learned in this lesson; then, the teacher asks the students to bring these questions, through independent exploration, cooperation and discussion between students, etc. To find the answer to the question. In this learning process, teachers can act as students, actively participate in student interaction, put forward their own ideas and problem-solving ideas, subtly guide students to think in the right direction, and improve students' problem ability and logical thinking ability. At the same time, teachers instruct students to further memorize knowledge points based on their understanding. Finally, teachers gradually guide students how to use the knowledge to solve practical problems, through exploration and practice, let students master the transfer and application of knowledge, and improve students' comprehensive learning ability.

3.4. Building a flipped classroom to effectively apply deep learning

Improving students' deep cognitive ability and creative ability is the main goal of deep learning. For this reason, it is necessary for teachers to adopt a scientific classroom teaching model to apply deep learning in depth. Flipped classroom is a new teaching model that emerged in the development of education informatization. It transfers the traditional teaching habit of "listening to teachers in class and doing homework after class" to the online + offline teaching model, that is, "before class the student watched the teacher's video explanation, then does the homework, (doing experiments) under the teacher's guidance in the classroom or used the knowledge the student learned to solve practical problems." Flipped classroom puts the knowledge transfer process of shallow cognition outside the class, and puts the process of knowledge internalization inside the class. It is also the main goal of deep learning to improve students' deep cognitive ability through teacher-student interaction and mutual exchange and learning between students. For example, before class, teachers can allow students to preview and learn new artificial intelligence courses by themselves through Massive Open Online Courses (MOOC), cloud classroom and other learning apps. During the learning process, the student should record the knowledge points they don't understand and submit them to the teacher before class. In class, after the teacher receives the questions and doubts raised by the students, he organizes the students to carry out practical activities, so that the students can further answer the questions through practice. After the practical activities, the teacher and the students will recall the knowledge points of the whole lesson together and establish an overall knowledge structure to help students consolidate the knowledge points and improve the students' ability to build a systematic knowledge system.

4. Concluding remarks

In summary, in the application of deep learning in artificial intelligence courses, the key points are based on understanding, building a systematic knowledge system, transferring and applying knowledge, and focusing on student experience and other elements. Based on this, in the actual application process, teachers should take student experience as the core and implement scientific teaching concepts; set deep learning goals based on curriculum standards; build a deep learning environment based on intelligent means; build effective applications in flipped classrooms Deep learning. Due to the limitation of the length of the article, the research on the application of deep learning in artificial intelligence courses in this article is not in-depth and complete. In the future, we should continue to pay attention to the relevant research dynamics of deep learning in artificial intelligence courses, and continuously enrich research experience to make up for the deficiencies of this article.

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Analysis of Core Technology Problems and Countermeasures in the Robot Industry

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Abstract: Since 2013, China has been the world's largest market for industrial robots. Despite the gradual maturity of the industrial robot system, the lagging R&D and backward technology level of industrial robots have led to a strong dependence on the import of core components and key technologies, which to a certain extent has restricted the development and improvement of industrial robots. At present, the "neck problem" in the field of industrial robots in China is not only in the reducer, controller, and servo but also in the basic processing equipment, basic technology, and basic materials. In this paper, we propose measures to improve the "neck problem" of industrial robots to promote the high-quality development of industrial robots in China.

Keywords: Industrial robots; "Neck problem"; Core components; Key technologies; Infrastructure equipment

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1. Introduction

At present, industrial robots play an indispensable role in the manufacturing industry, significantly improving product production efficiency and quality. Along with the rapid development of the world economy, the manufacturing industry is becoming increasingly competitive, and the development and popularization of industrial robots not only improves the efficiency of the manufacturing industry but also enhances the advantages of China's manufacturing industry in the international competition system and can accelerate the transformation and upgrading of China's industry.

Although China's industrial robots ranked first globally in terms of cumulative installed capacity in 2019, the "neck problem" still exists in core components and key technologies. In this paper, through a systematic review and analysis of the "neck problem" of China's industrial robots and the subdivision of China's industrial robot manufacturing process, we conclude that the crux of the "neck problem" is not all the three major components in general, but also exists in It is also found in the essential equipment, process, materials, and other aspects. This paper provides theoretical, practical, and policy references to accelerate the solution of the "neck problem" of industrial robots in China by strengthening basic research, disruptive innovation, setting up special R&D funds, strengthening collaboration between industry, academia, and research institutes, and introducing and cultivating top scientific and technological talents and artisanal talents.

2. History of China industrial robot development

The development of industrial robots in China has gone through four stages: in the first stage (1970s to early 1980s), the basic theory of industrial robots was studied, and some progress was made in robot kinematics and mechanics, which laid the foundation for future industrial robot research [1]; In the second stage (mid-1980s), the government attached importance to and supported the development of industrial robots. The state organized surveys on industries requiring industrial robots and invested a lot of money in the research of industrial robots [2]; In the third stage (1990s), seven kinds of industrial robots were developed, and more than 100 robot application projects were implemented, which promoted the industrialization of domestic robots; In the fourth stage (21st century), the government actively created a policy environment conducive to independent innovation, accelerated the promotion of enterprises to become the main body of innovation, and vigorously advocated enterprise-oriented, industry-oriented, and industrial robots [3].

With the advancement of robotics to meet the increasing demand of automated production, robots dominate the third industrial revolution, in which a new generation of robots with intelligence as the core, high-speed networks, and cloud storage robots become the terminals and nodes of the Internet of Things [4]. The world's developed countries have elevated robotics development to the height of national strategy, and many countries have taken robotics as an important entry point to enhance competitiveness. British economist Paul McGillivray believes that the third industrial revolution based on the Internet, materials, and energy, with "digital intelligent manufacturing" as the core, is coming, and the main body of "intelligent digital manufacturing" is industrial robots [5]. As important basic equipment for a country's industrial development, industrial robots are an essential symbol of a country's scientific and technological innovation and manufacturing level, which can promote industrial transformation and upgrading and is also an important entry point to accelerate the construction of a strong country.

3. China's industrial robots and core components development status

3.1. The current situation of industrial robots

Marked by the high-speed promotion of industrial Internet development, China's robotics development has been remarkable under the continuous support and promotion of national policies, enterprises, funds, and other production factors. 2013 became the world's largest industrial robot market, with about 140,500 new industrial robots installed in 2019. According to the China Electronics Association, the global robotics market size reached \$29.41 billion in 2019; China is about \$8.68 billion, of which \$5.73 billion for industrial robots, accounting for about 66% of the robotics market share. In addition, according to the National Bureau of Statistics data, the annual production of industrial robots in China has gradually increased since 2002, and the production in 2019 was 186,943 sets, an increase of 26.6% compared with 2018, accounting for 50.1% of the total global production. The average density of industrial robots worldwide in 2019 was 114 sets/million people, and the installed density of industrial robots in China was 187 sets/million people. The global ranking is 15th, which is higher than the world average, but there is still a gap compared with developed robotics countries, which shows that there is still a large upside in China's robot density.

3.2. The status of core components

In industrial robot R&D technology, reducers, servers, and controllers are the three most challenging core components and the most profitable segments, accounting for 36%, 24%, and 12% of the total cost of industrial robots, respectively. Core components and critical technologies determine essential performance indicators of robots, such as accuracy, load capacity, stability, and reliability. Having core components and key technologies can occupy the high ground in the field of industrial robots.

(1) In terms of reducer, due to the late start of China's industrial robots, infrastructure, technology level backward and other reasons, resulting in most of the domestic industrial robots using reducers dominated by foreign enterprises. Along with the development of China's industrial robots, from the product classification, the domestic harmonic reducer progresses relatively fast, at present, Suzhou Green Harmonic Transmission Technology Co. The development of R.V. reducer is

relatively slow, and there are relatively few manufacturers who can mass-produce, and it is a little weak in market share and brand degree.

(2) Servo, with the progress of science and technology, A.C. servo system technology is becoming more and more mature, the cost continues to decline, A.C. servo motor gradually replaced D.C. servo motor to become the mainstream of mechatronics technology production system motor, in industrial robots, CNC machine tools, and other fields, the application of A.C. servo system is becoming more and more widespread [6]. Although China's servo system in the quality and technical level is progressing, compared with internationally renowned enterprises, the overall performance and reliability there are more problems, foreign enterprises about 80% occupy the domestic high-end server market.

(3) controller, although the controller in the core components accounted for a relatively low but plays a vital role in robot control. The process of control system development, it involves many core technologies such as hardware design, underlying software technology, and upper layer function application software. Through years of precipitation and technology accumulation, the gap between domestic brands and foreign brands in the controller hardware platform is gradually narrowing. However, due to the lack of platform foundation, most of the controllers produced by domestic manufacturers use a closed structure, its poor openness, poor software independence, fault tolerance, poor scalability, lack of network functions, it is difficult to adapt to the requirements of intelligence, flexibility [7].

4. The key technology is the "neck problem"

4.1. (R.V.) reducer domestic technology is weak, and the import volume is large

At present, about 75% of the world's precision reducers are monopolized by two Japanese companies, Nabtesco and Harmonic Drive, of which, Nabtesco's R.V. reducer accounts for about 60% of the market share and Harmonic Drive accounts for 15% of the market share. R.V. reducer is a two-stage closed transmission mechanism based on the cycloidal planetary reducer. Closed transmission mechanism, due to its small size, strong impact resistance, high torque, high positioning accuracy, slight vibration, large reduction ratio, widely used in industrial robots, machine tools, medical testing equipment, satellite receiving systems, and other fields, its fatigue strength, stiffness, life, and other performance are better than the general robot harmonic transmission, and the return accuracy is stable, many countries in the world high-precision robot transmission mostly use R.V. reducer. R.V. reducer has the trend of gradually replacing harmonic reducer in the advanced robot drive [8]. There are no outstanding enterprises in China's R.V. reducer enterprises, and the development of R.V. reducer is based on high technology and high investment as the primary threshold, which causes difficulties for R&D enterprises to enter the market. The technical level of R.V. reducer in China has more precision, stability, speed, noise, life, etc., especially in the "neck problem" in the development system of industrial robots.

4.2. The server and the leading international enterprises technology problem points

The server is the engine that controls the operation of mechanical components in the servo system of industrial robots, a kind of variable speed device between subsidized motors. The server is generally installed in the robot's "joints", which is the heart of the robot movement. Domestic high-end servers are monopolized by foreign enterprises by nearly 80% market share, the Japanese servo products stable performance can meet the requirements of most applications, especially small power motors, the advantages are relatively obvious, the advantages of European products in high-speed and precision areas more obvious. Server manufacturing high-temperature-resistant materials, encoder technology, feedback components, magnetic materials, power modules mainly rely on imports, is the focus of the development of China's server "neck problem." Imported and domestic servers can be seen, domestic server signal plug-in, response speed, pulse frequency, resolution, work accuracy and other aspects of the leading international enterprises, and the gap are relatively obvious.

4.3. The controller in the software level to be improved

The controller is called the "brain" of the industrial robot, and its performance plays a crucial role. Its main task is to control the robot's motion position, attitude, and trajectory in the working space [9]. The industrial robot controller mainly includes hardware and software parts. As most of the hardware is outsourced, almost all industrial robot suppliers can purchase the same hardware. The main problem of domestic and foreign robot controllers is reflected in the software part, that is, the control algorithm and the ease of use of the secondary development platform [10], which is the focus of the "neck problem" in the development of China's industrial robots in the controller. Domestic controllers are relatively lacking in operational stability, applicability, and precision due to the lack of software technology, causing the domestic controller market to be occupied by foreign countries with a larger market share. With the accumulation of domestic robot technology and application experience, domestic controller products are relatively mature and are the core components with the smallest technological gap with foreign countries.

In addition, in the basic processing equipment and materials, due to technical and technological problems, resulting in the production of parts in the stability, precision, reliability and other aspects of the severe shortage. For example, parts processing equipment in the machine tool equipment high-end technology is still monopolized by foreign countries, especially CNC machine tools supporting equipment 90% need to be imported, most of the key zero parts are controlled by Germany, Japan. China's high capacity in steel, aluminum, copper, and other metals, although it can replace the demand for some products, due to the demand for industrial robots' core parts quality, some companies still need to rely on imported materials. Basic processing equipment, technology, and materials are also important factors leading to the "neck problem" of industrial robots.

Industrial robots play an important role in China's economic development and can effectively optimize the economic structure and diversify, rationalize, and make China's economic industry more efficient, and the development of industrial robots is the top priority of China's development at this stage. The "neck problem" is reflected in the technical aspects, including basic equipment and basic materials. Due to the monopoly of technology by developed countries in China, the cost of industrial robots remains high, so that many enterprises in China cannot enjoy its value, which directly affects the development of enterprises and has a huge impact on China's economy, national security and industrial security.

5. Suggestion

5.1. Set up a special R&D fund for robotics to help solve the "neck problem" of key technologies

Because of the late exploration of scientific research for robotics in China, the research and development capability are relatively weak, the technology is backward, the performance is poor, and the strength is disparate compared with the developed countries of Japan and Europe robotics. The ratio of basic research to R&D funding in developed countries is about 15%-25%, while the ratio of basic research to R&D in China is only about 1/3 to 1/5 of theirs [11]. The core components and key technologies of robots require a high technical level and more difficulties, which are part of a long R&D cycle, high investment, and high energy consumption, requiring a long time and high investment to effectively promote technological progress. China's scientific research is basically centered on universities and research institutes, and the investment in special R&D can improve the research equipment and research environment and also stimulate the innovation vitality, efficiency, and enthusiasm of researchers to achieve more original results, thus enhancing innovation and creativity. The establishment of special core R&D can speed up the conversion rate of basic and applied research results and has a positive effect on the improvement of the "neck problem."

5.2. Adopt disruptive innovation

Disruptive innovation refers to replacing imports with domestic production, cutting into the "neck" problem point, improving product quality and service level, subverting the existing market pattern, destroying the domestic monopoly, breaking through the existing business model, increasing the localization rate and achieving a bend in the road. The essence of disruptive innovation is technological innovation, which can promote product innovation and corporate breakthroughs, bring new business models and open up new markets. Disruptive innovation requires precise positioning and analysis of the market, grasping the internal and external market environment, and strengthening basic research in order to effectively implement disruptive innovation strategies.

5.3. Enterprise-based, to strengthen the collaborative innovation of industry, academia, and research

Science and technology innovation is an important driving force for economic and social development, and it is important to build an industry-university-research collaborative innovation system with enterprises as the main body. At present, China's science and technology power is mainly distributed in scientific research institutions and universities, and enterprises' science and technology R&D power is relatively weak, with little R&D investment, few R&D institutions and weak innovation ability. Enterprises should take the national support as an opportunity to actively cultivate the awareness of scientific and technological research, strengthen the collaborative innovation of industry-university-research, breakthroughs in basic equipment, basic processes, basic materials and other issues, and accelerate the rate of transformation of scientific and technological achievements.

5.4. Strengthen the introduction and cultivation of talents and enhance the level of basic research

The lack of professional talents is an important factor restricting the development of industrial robots in China. In terms of talent introduction and cultivation, we will vigorously implement the plan of introducing high-level innovative talents, actively introduce and cultivate innovative high-end talents and artisan talents, establish and improve a reasonable talent introduction and cultivation mechanism, enhance the basic research and innovation capability of China's industrial robots, and promote the further enhancement and development of core components and key technologies of China's industrial robots.

6. Conclusions

The demand for industrial robots is growing, and the market size of industrial robots is growing every year and is expected to have higher growth space in the future. To break through the status quo of core field constraints, we also need our own continuous efforts and innovation to turn problem points into motivation, focus on breaking through core field problems, and make the core field of industrial robots into a completely independent and controllable production mode, so as to break the bottleneck of industrial robot use.

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Applications and Challenges of Deep Reinforcement Learning in Multi-robot Path Planning

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Abstract: With the rapid advancement of deep reinforcement learning (DRL) in multi-agent systems, a variety of practical application challenges and solutions in the direction of multi-agent deep reinforcement learning (MADRL) are surfacing. Path planning in a collision-free environment is essential for many robots to do tasks quickly and efficiently, and path planning for multiple robots using deep reinforcement learning is a new research area in the field of robotics and artificial intelligence. In this paper, we sort out the training methods for multi-robot path planning, as well as summarize the practical applications in the field of DRL-based multi-robot path planning based on the methods; finally, we suggest possible research directions for researchers.

Keywords: MADRL; Deep reinforcement learning; Multi-agent system; Multi-robot; Path planning

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1. Introduction

Multi-agent systems (MAS) are distributed computing approaches that can be used to a wide range of issues, including robotics, distributed decision making, traffic control, and corporate management. MADRL is a DRL application for MAS, in which agents interact in the same environment, with each agent formulating a policy at each time step using DRL algorithms to collaborate with other agents to achieve a goal. Path planning is the foundation for mobile robot navigation and control, and several robots can complete big and complicated tasks more effectively than a single robot. Many classical methods are used to solve path planning problems for multiple robots, such as graph search algorithms and heuristic algorithms, commonly known as A* algorithms, artificial potential field methods, and ant colony optimization algorithms. Next, path planning methods are classified into centralized and decentralized methods according to the structure of the robot.

2. Multi-agent deep reinforcement learning

DRL is considered an important component for building general-purpose artificial intelligence systems and has been successfully combined with techniques such as search and planning. It has also been combined with MAS in recent years to form the emerging field of MADRL. This section provides a brief classification of MADRL.

Analysis of emergent behaviors is a direct extension of the single-agent DRL algorithm in a multi-agent environment, where there is no communication between the agents, either for training or execution. In a multi-agent environment, all the agents independently interact with the environment and form behavioral strategies independently. In this approach, the number of actions grows exponentially, which makes the problem difficult to solve.

Learning communication is the sharing of information and experiences observed by each of the agents through communication. It is assumed that the agent interacts with other agents through its own local observations with explicit information between them. After training and learning, the agents must make behavioral decisions about which agents to cooperate with based on the transmitted information. This approach is suitable for both fully cooperative tasks and incompletely observed environments.

Learning cooperation is a problem of cooperative strategies for agents to learn complex, partially observable domains without explicit communication. The cooperative problem can be formulated as a decentralized partially observable Markov decision process (Dec-POMDP), where all the agents try to maximize the discounted sum of joint rewards, and the agents do not communicate explicitly and learn cooperative behavior only from their respective observations.

Agent modelling is a technique in which an agent anticipates the behavior of a modelled agent by using models to reason about the behavior of other agents. The Deep Recurrent Opponent Network (DRON) consists of two networks: one to evaluate the Q value and another to learn the adversary agents' strategy, as well as many expert networks operating simultaneously to improve the algorithm's capabilities. The Agents modelling agents' algorithms are more resilient and have a broader range of application scenarios, but modelling complexity is high and practical applications are limited. Deep reinforcement learning-based path planning for multi-agent system.

2.1. Classification of multi-robot path planning training methods

The multi-robot path planning training methods can be grouped into three:

(1) Centralized. The centralized training scheme assumes that the actions of all the agents are determined by a central server that knows the intentions of all the agents. The centralized approach has three limitations. First, the computational complexity of centralized control and scheduling is high as the number of robots increases; second, the centralized approach cannot scale to large-scale systems because of communication problems; and third, the centralized system is susceptible to failures in the central server, communications between robots, or sensors on any individual robot.

(2) Decentralized. Decentralized systems are more flexible, more efficient in task completion, and more fault-tolerant. In decentralized training methods each agent learns its own strategy by considering the observable states of other agents, such as shape, velocity and position, maps its own observations to actions to make decisions independently, and each agent calculates paths individually and then adjusts these paths to avoid conflicts. Decentralized approaches are also divided into reaction-based and trajectory-based approaches.

(3) Shared parameter. The path planning is decentralized, but the learning process is centralized. This approach is able to exploit the capabilities of each robot and compensate for the shortcomings of centralized path planning, thus adapting to unknown planning environments, while the method does not require knowledge of the dynamics model of the environment, has no communication requirements, and can be used in both cooperative and competitive environments. However, it also requires a central coordinator, it is not fully autonomous, and it is poorly scalable. Therefore, it does not support the training of a large number of agents and has a long training period.

2.2. DRL multi-robot path planning method

Table 1 summarizes the DRL multi-robot path planning methods and the advantages and limitations of each method. From the information in **Table 1**, it can be summarized that shared parameter type algorithms such as MADDPG and ME-MADDPG can be used in dynamic and complex environments [1-4]; decentralized architectures such as DQN and DDQN can be considered in stable environments [5-7]; large robotic systems facing a large number of dynamic obstacles can be considered using algorithms such as A2C, A3C and TDueling [8-11].

Table 1. DRL multi-robot path planning method

References	Objectives	Main Algorithm	Advantages	Limitations
[1]	Solving the problem of slow learning of decentralized path planning in unknown environments.	Q-learning, kernel smoothing, neural networks	1. Overcoming the disadvantages of slow and time-consuming learning in RL. 2. Not seriously affected by sensor fluctuations.	The efficiency of the method decreases as the number of agents increases.
[2]	Solve the problem of multi-robot collision-prone under vision-based.	DQN	1. No need to manually mark feature values. 2. High collision avoidance success rate.	1. Slow learning efficiency. 2. Unable to scale to large-scale robot teams. 3. Can't detected Target information.
[3]	Solving Path Planning Problems in Warehouse Environments.	DQN	Using a priori knowledge and rules to guide path planning, which improves the learning efficiency of the algorithm.	Suitable for small-scale robotics teams.
[4]	Solving path planning problems in hybrid dynamic environments.	A2C	1. Does not require homogeneous agent; 2. Higher success rate and more stable performance.	Only simulation experiments are conducted, and the effectiveness is not proven in a real environment.
[5]	Solving the path planning problem of multi-robot systems in the process of information sharing.	TDueling	1. Solves the problem of source competition and obstacle avoidance; 2. The algorithm has higher accuracy and better robustness.	In a three-dimensional environment, the training time and complexity are significantly increased and generalization is lacking.
[6] [7]	Addressing Lifelong MAPF in High Density Structured Environments	IL, A3C, LSTM	1. Suitable for large-scale robotic teams; 2. Short training time.	The robots do not communicate with each other and do not take advantage of the collaboration of multi-robot systems.
[8]	Solving the collision problem in path planning.	MAPPO	1. Effectively apply to real-world tasks. 2. No need to create a barrier map of the environment.	1. Algorithm training time is long. 2. Validation on only a few teams of agents.

[9]	Solving the problem of target assignment and path planning for collaborative multi-UAV control systems.	MAD DPG	1. Dealing effectively with dynamic environments. 2. Real-time planning performance can be guaranteed.	1. Long training time. 2. Validation on only a few teams of agents.
[10]	Solving UAV ground target tracking problems in obstacle environments.	MAD DPG	1. High real-time planning. 2. No need to converge in the optimization process.	1. Long training time; 2. Vision-based DRL methods cannot detect the target location information.
[11]	Solving multi-agent body motion planning problems in dynamic and complex environments.	ME-MAD DPG	1. Fast convergence and high convergence value. 2. Good stability and adaptability.	Validity validated on only a few teams of agents.

3. Challenges and research directions of DRL-based multi-robot path planning

Recently, the research on DRL-based multi-robot path planning has made great progress, but there are still some problems in the algorithm because of the complexity of the environment, so the future research on DRL-based multi-robot path planning can be carried out from the following aspects.

(1) Improved generalization capability. DRL-based multi-robot path planning problems often use neural networks to process sensor data, and although the results perform well in the training environment, they lack generalizability from one environment to another and from the simulated environment to the real environment.

(2) Improving the sampling efficiency of the algorithm thus speeding up the learning speed. When the environment is more complex, the amount of data will be larger and the number of interactions between the intelligent body and the environment will be more. Most of the existing studies use empirical playback techniques to improve the sampling efficiency of the algorithm, but cannot guarantee the data in real time.

(3) Set a more efficient reward function and thus improve the exploration efficiency. In the path planning problem, model-free DRLs will rely on exploration to find the optimal policy, but because there is sparsity in rewards, the agent will only be rewarded when it reaches the goal, so the agent will perform many meaningless exploration behaviors in the environment. The reward function must be designed precisely, otherwise the reward function will be learned over-fittingly.

(4) Model-based learning. Model-free DRL algorithms require a large amount of sampled data for training, which is often difficult to obtain through interaction. Therefore, it is possible to consider using existing data from realistic environments to build environmental models, which can then be used to train the agents. Combining model-based algorithms and model-free deep reinforcement learning path planning problems is one of the key ways to improve the efficiency of reinforcement learning in the future.

4. Conclusion

In recent years, mobile robotics has been a prominent study topic, and path planning is a key technology for robots and self-driving cars. The literature on DRL-based multi-robot path planning in the previous five years is briefly summarized in this study. In addition, future research prospects for DRL-based multi-robot path planning are discussed. Many DRL path planning algorithms are still in the laboratory stage, and there are still big disparities between them in terms of current development state. Also, path planning conditions in real environments, including environmental uncertainties, communication and data delays, which pose many challenges for the DRL "trial-and-error" training approach, and also for future DRL research in the field of path planning. These are challenges for DRL's "trial-and-error" training approach, and are also problems to be solved in future DRL research in the field of mobile robot path planning.

Disclosure statement

The author declares no conflict of interest.

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RHMX: Bus Arrival Time Prediction via Mixed Model

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Abstract: With the widespread use of information technologies such as IoT and big data in the transportation business, traditional passenger transportation has begun to transition and upgrade into intelligent transportation, providing passengers with a better riding experience. Giving precise bus arrival times is a critical link in achieving urban intelligent transportation. As a result, a mixed model-based bus arrival time prediction model (RHMX) was suggested in this work, which could dynamically forecast bus arrival time based on the input data. First, two sub-models were created: bus station stopping time prediction and interstation running time prediction. The former predicted the stopping time of a running bus at each downstream station in an iterative manner, while the latter projected its running time on each downstream road segment (stations as the break points). Using the two models, a group of time series data on interstation running time and bus station stopping time may be predicted. Following that, the time series data from the two sub-models was fused using long short-term memory (LSTM) to generate an approximate bus arrival time. Finally, using Kalman filtering, the LSTM prediction results were dynamically updated in order to eliminate the influence of aberrant data on the anticipated value and obtain a more precise bus arrival time. The experimental findings showed that the suggested model's accuracy and stability were both improved by 35% and 17%, respectively, over AutoNavi and Baidu.

Keywords: IoT; Big data; Bus arrival time prediction; Long short-term memory; Kalman filtering

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1. Introduction

With the evolution of urban public transportation systems and changes in user travel preferences, providing consumers with exact bus arrival time prediction service has become a vital component in the development of intelligent transportation. In order to construct a city-level real-time dynamic bus transfer system and execute the intelligent transportation concept of "Mobility as a Service," bus arrival time must be properly forecasted. As a result, bus arrival time prediction technology has become a hotspot for study, which may be examined in the following ways:

(1) Bus arrival time prediction model based on historical data

The historical data model was first used to estimate bus arrival times. Based on historical data, such a model uses a big data platform to assess the bus running laws in each time frame, and then collects bus running time in each time frame [1-5]. The historical data model is based on the original data, which means that the data from the earlier moment must not alter significantly from the current data. Any emergency circumstance may cause data to be modified rapidly, resulting in a significant loss of accuracy, therefore the stability is weak.

(2) Bus arrival time prediction model based on Kalman filtering

According to the optimal estimated value at the previous moment, the Kalman filtering algorithm can forecast the present optimal estimated value. Because of its powerful antijamming capacity, this model has a high level of stability. When utilized to address the bus arrival time prediction problem, it is cable to reduce the disturbance from the external environment, with a relatively high forecast accuracy [6-7]. Furthermore, it may dynamically alter the projected bus arrival time, resulting in good timeliness; nevertheless, the prediction effect decreases as the number of iterations increases.

(3) Bus arrival time prediction model based on particle filtering

Particle filtering, which can solve the problems existing in the Kalman filtering algorithm, approximately expresses a probability density function by seeking for a group of random samples propagated in a state space, and replaces integral operation with sample mean, so as to acquire the minimum variance estimate of the system state [8]. The bus arrival time prediction problem has been investigated by many scholars through particle filtering [9-12], with good nonlinear processing capacity, but the sample diversity will be degraded due to the resampling process.

(4) Bus arrival time prediction model based on regression model

A regression model is a mathematical equation that is used to objectively assess the relationship between independent variables and dependent variables in order to establish the causal relationship. The dependent variable, bus arrival time, is often predicted based on influencing factors such as weather and distance between road segments, which are independent variables [13-14]. However, because it is difficult to determine, this mathematical model is rarely employed.

(5) Bus arrival time prediction model based on neural network

Even if no formal model is constructed, neural networks can be used to tackle some practical problems due to its strong adaptative ability, generalization ability, and nonlinear processing capacity. When it comes to bus arrival time prediction, neural network models may learn not only the relationships between different vehicles on the same route at different times, but also the spatial relationships between distinct road segments. Many researchers have looked into this [15-18], and high prediction accuracy has been established.

2. Model Introduction

2.1. Feature engineering

The prediction of bus stopping time is influenced by both station dwell time and bus running time, which are affected mainly by the following factors:

The related data were collected specific to the above influencing factors, and a total of 708,270 records were included. In order to reduce the prediction error, the data of all holidays and festivals were eliminated, while only the data of working days and rest days were reserved. The GPS data reissued after a delay were placed into the GPS series in chronological order. The data points (totally 1,387) with GPS abnormality were eliminate, and the overall data size collected in this study could be neglected. The GPS data without weather factors were supplemented by historical weather data.

The bus arrival time was influenced by a variety of parameters, as shown in **Table 1.**, although only a few of them were effective. As a result, elements from the bus arrival time prediction model have to be chosen carefully in order to extract the most useful features from the original data.

(1) Feature selection of bus stopping time prediction model

In this study, multiple hypothesis testing was adopted as the feature selection model for this model. In order to judge the correlations between features and variables, F value should be calculated through formulas (1) and (2):

$$ri = \frac{(X[:,i] - mean(X[:,i]))(y - mean(y))}{std(X[:,i])std(y)} \quad (1)$$

$$F = \frac{r_i^2}{1 - r_i^2} * (n - 2) \quad (2)$$

Where $X[:,i]$ represents the feature i, $mean(X[:,i])$ is the mean value of feature i, y is the target value, $mean(y)$ stands for the mean value of target value, $std(X[:,i])$ is the standard deviation of feature i, and $std(y)$ is the standard deviation of target value. P value could be calculated according to the F value and degree of freedom, which served as the basis for feature selection. Through the parameter adjustment, it was suitable to take the significance level as 0.042. In other words, the original hypothesis was rejected if the P value was smaller than 0.042, and the feature was correlated with the dependent variable. If the P value was greater than 0.042, the feature was uncorrelated with the dependent variable. The P values of all features are listed in **Table 2**.

Table 1. Influencing Factors of Bus Arrival Time Prediction

Influencing factor	Concrete type
Weather factors	Temperature, wind direction, wind power, humidity, reporting time, concrete weather type
Vehicle factors	Vehicle No., vehicle direction, longitude and latitude of vehicle position, next station No., bus distance to the next station, instantaneous speed of bus, signal intensity at vehicle terminal, running distance on the same day, GPS uploading time
Station factors	Station longitude and latitude, quantity of institutions of higher learning around station, quantity of middle schools, quantity of primary schools, quantity of scenic spots, quantity of bus routes, quantity of dining places, quantity of shopping places
Time factors	Date type (holidays and festivals, working days, rest days) and time frames
Road factors	Road segment No., quantity of traffic lights, quantity of confluences, length of road segment, quantity of institutions of higher learning, quantity of middle schools, quantity of primary schools, quantity of kindergartens, quantity of scenic spots around road segment, quantity of bus routes on the road segment, quantity of dining places around road segment, quantity of shopping places around road segment

Table 2. P Values of Features of Bus Stopping Time Prediction Model

Feature	P value	Whether to choose the feature	Feature	P value	Whether to choose the feature	Feature	P value	Whether to choose the feature
Bus No.	0.021	Yes	Wind power	0.033	Yes	Quantity of kindergartens	0.036	Yes
Next station No.	0.025	Yes	Humidity	0.032	Yes	Quantity of dining places	0.022	Yes

Signal intensity	0.065	No	Date type	0.029	Yes	Quantity of shopping places	0.029	Yes
Running distance	0.038	Yes	Quantity of station routes	0.031	Yes	Station longitude	0.028	Yes
Time frame	0.025	Yes	Quantity of scenic spots	0.036	Yes	Station latitude	0.025	Yes
Weather	0.045	No	Quantity of institutions of higher learning	0.026	Yes			
Tempera ture	0.036	Yes	Quantity of middle schools	0.031	Yes			
Wind direction	0.032	Yes	Quantity of primary schools	0.032	Yes			

As seen in **Table 2**, there were totally 19 features with P values greater than 0.042. It is common sense that signal intensity is only associated with data transmission quality but unrelated to bus stopping time prediction. Only six weather conditions were considered in this study, namely, light rain/overcast/cloudy/sunny/rainy/foggy. The weather features could already characterize the temperature, wind direction, wind power and air humidity, so they were excluded.

(2) Feature selection of bus interstation running time prediction model

Multiple hypothesis testing was still selected for the feature selection of bus interstation running time. Through the parameter adjustment, a suitable significance level was 0.05, and the P values of all features are presented in **Table 3**:

Table 3. P Values of Features of Running Time Prediction Model

Feature	**P value**	**Whether to choose the feature**	**Feature**	**P value**	**Whether to choose the feature**	**Feature**	**P value**	**Whether to choose the feature**
Bus No.	0.021	Yes	Data uploading time	0.041	Yes	Quantity of confluen ces	0.036	Yes
Direction of bus head	0.025	Yes	Weather	0.039	Yes	Length of road segment	0.032	Yes

Current bus longitude	0.04	Yes	Temperature	0.053	No	Quantity of bus routes	0.039	Yes
Current bus latitude	0.038	Yes	Wind direction	0.054	No	Quantity of scenic spots	0.033	Yes
Next station No.	0.025	Yes	Wind power	0.054	No	Quantity of institutions of higher learning	0.035	Yes
Current speed	0.045	Yes	Air humidity	0.056	No	Quantity of middle schools	0.044	Yes
Signal intensity	0.066	No	Date type	0.041	Yes	Quantity of primary schools	0.045	Yes
Bus running distance on the same day	0.042	Yes	Quantity of traffic lights	0.04	Yes	Quantity of kindergartens	0.042	Yes
Quantity of dinning places around road segment	0.032	Yes	Quantity of shopping places around road segment	0.036	Yes			

(3) Acquisition of bus interstation running time

In order to select a proper bus interstation running time prediction model, the approximate value of bus interstation running time should be acquired from historical data through the following method:

Algorithm 1: Estimation of running time on road segment

Input: Original GPS dataset $RawGpsData_i=\{gpsdata_1, gpsdata_2, \ldots, gpsdata_n\}$
Output: Bus running time set $R_j=\{r_1, r_2, \ldots, r_n\}$ on road segment
Initialize the dataset m = 1, D_i^m, PD_i^m, GD_j^k // of bus i
while m <= length (RawGpsData) do
    if $RawGpsData_m \in d^n$ then
        D_i^n.append($RawGpsData_m$);
    m = m + 1;
end while
PD_i^m= sortByTime(D_i^n) //GPS dataset arranged in chronological order
GD_{mj}^k = getSetOftrip(PD_i^m); //GPS dataset of bus m in each trip on each road segment
while j <= length(GD_{mj}^k) do
    Pet = gd_{mj}^k[time]

```
Pst = gd^k_{m1}[time];
Rt = Pet – Pst;
R_j.append(Rt);
j=j+1;
end while
return R_j;
```

First, the original GPS data were classified according to the bus number. The GPS dataset under each bus number was $D_i^m = \{\{d_1^1, \dots, d_z^1\}, \dots, \{d_1^n, \dots, d_z^n\}\}$. Next, the data points under each bus number were ranked in a chronological order, thus obtaining a ranked set $PD_i^m = \{\{pd_1^1, \dots, pd_z^1\}, \dots, \{pd_1^n, \dots, pd_z^n\}\}$. The GPS dataset PD_i^m of bus m was acquired, and then the GPS dataset $GD_j^k = \{\{gd_1^1, \dots, gd_j^1\}, \dots, \{gd_1^k, \dots, gd_j^k\}\}$ of bus m in each strip on each road segment was acquired according to the serial number field of next station in the original GPS dataset. Subsequently, GD_j^k was traversed to acquire the first GPS point gd_1^k and the last GPS data point gd_j^k of bus m in the trip k on each road segment, and the bus running time Rt on this road segment was obtained by deducting the uploading time Pst of the first GPS data point gd_1^k from the uploading time Rt of the last GPS data point gd_j^k, as shown in **Figure 1**.

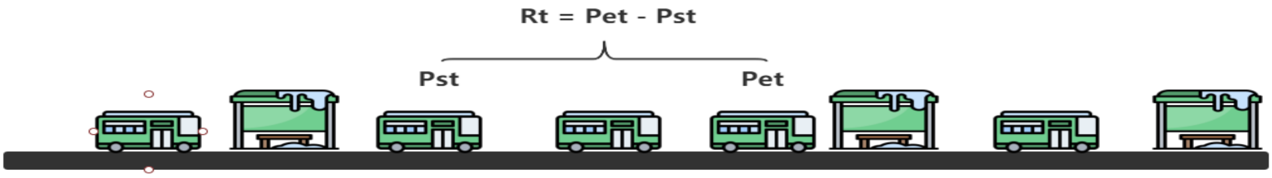

Figure 1. Calculation of Running Time on Road Segment

(4) Acquisition of bus stopping time

In order to choose a suitable bus stopping time prediction model, the approximate value of bus stopping time should be sought from the historical data through the following method:

The calculation steps of bus stopping time were basically identical with those of bus running time. The difference lied in that the last GPS point Pe of bus m in the trip k on the road segment n and its first GPS point Ps on the road segment n+1 were acquired in the traversal process of GD_j^k. The stopping time Ts of bus m at station n+1 in the trip k was calculated by deducting the uploading time Pet of Pe from the uploading time Pst of Ps, as shown in **Figure 2**.

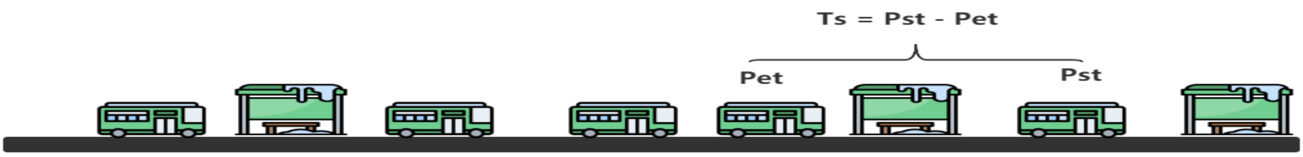

Figure 2. Calculation of Bus Stopping Time

2.2. Framework of arrival time prediction model

In the running process, a bus had two running states: interstation running state and stopping state at station. Without consideration of emergencies, the estimation of bus arrival time was a linear superposition of running time on each road segment and stopping time at each station, but the actual bus running laws could not be accurately described through such simple linear superposition. Since many factors should be considered in bus running process, the prediction result obtained through linear superposition deviated a lot from the reality in case of any emergency. Therefore, a new bus arrival time prediction model was proposed in this chapter to eliminate the error of such linear superposition, with the model framework as shown in **Figure 3**:

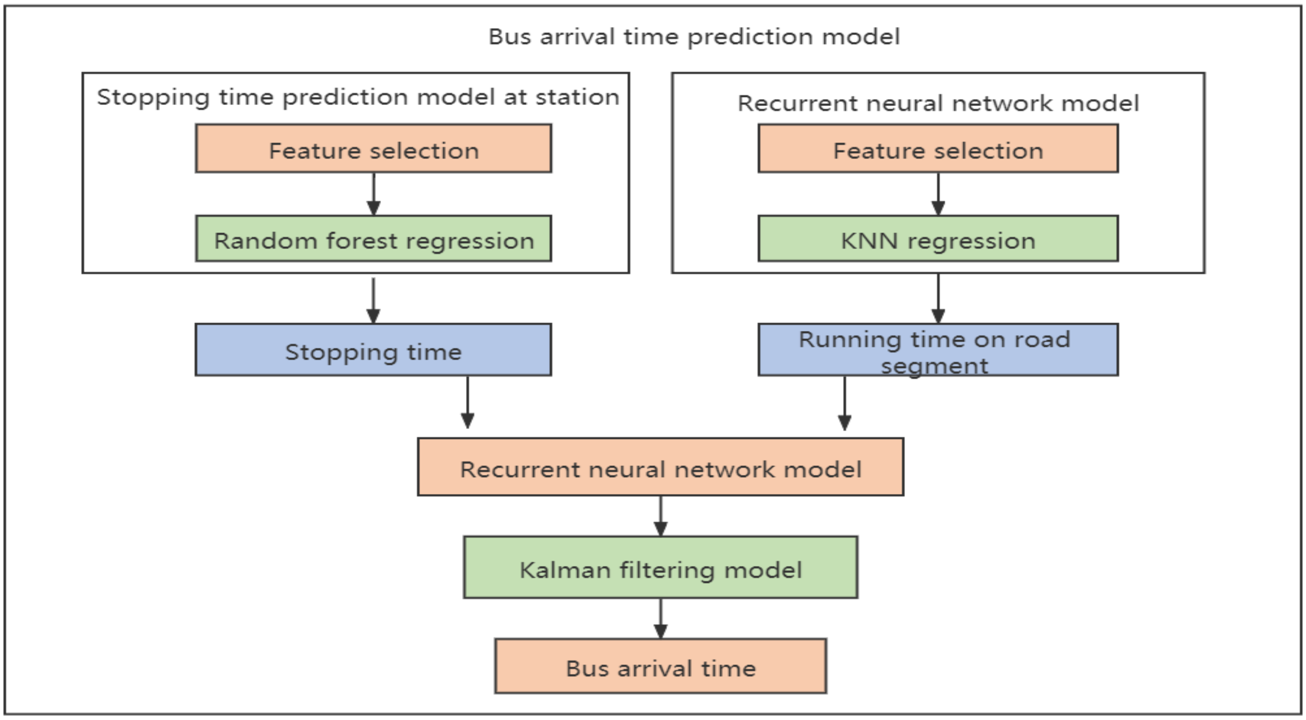

Figure 3. Bus Arrival Time Prediction Based on Fixed Model

The blended model was principally partitioned into three sections: two sub-models and one fixed model, separately being halting time expectation model at station, interstation running time forecast model and LSTM blended model, among which the first was utilized to anticipate the transport preventing time at each station from the spot of takeoff to the objective, the subsequent model was utilized to foresee the transport running time on every street portion from the spot of flight to the objective, and the contribution of LSTM blended model was the time series information consolidating the running time on every street fragment and halting time at each station yield by the two sub-models. Kalman separating model was utilized to progressively address the results, lastly acquire the anticipated appearance season of transport at the objective.

2.2.1. Stopping time prediction model at station

In this study, random forest regression model was selected to predict the bus stopping time after a comparison with multiple models. In the constructed random forest model, boostrap method was selected to divide each tree model training set. To construct the model, the maximum quantity of features (stn), minimum sample size of leaf nodes (tln) and quantity of subtrees (ctn) used by a single decision tree should be determined. In the end, the mean value of all subtree prediction results was taken as the predicted value of bus stopping time at station, as seen in formula (3). The established random forest model is as shown in **Figure 4**.

$$S_t = \frac{\sum_1^{ct_n} PT_i}{ct_n} (1 \leq i \leq ct_n) \tag{3}$$

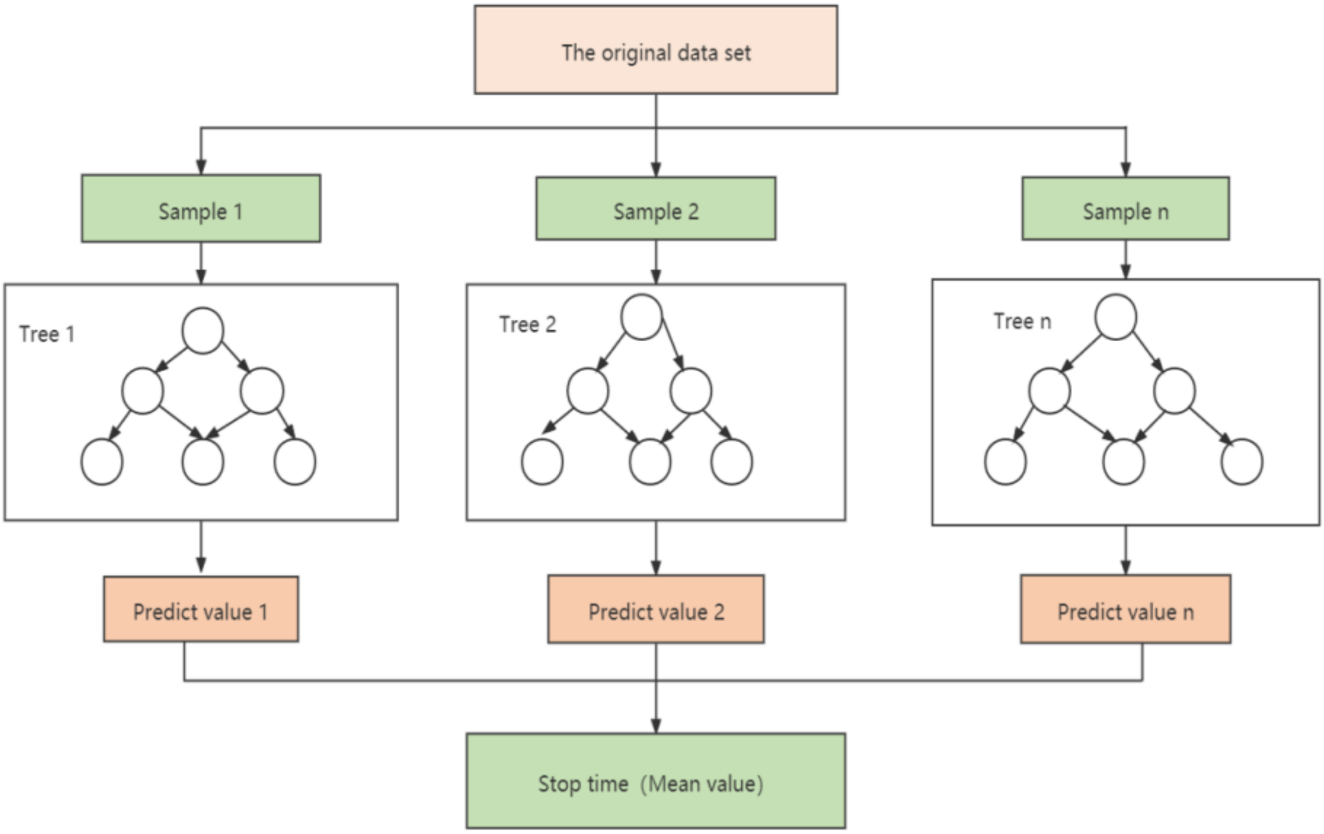

Figure 4. Random Forest Regression

2.2.2. Interstation running time prediction model

In this study, the KNN regression model (**Figure 5**) was used to predict the bus interstation running time.

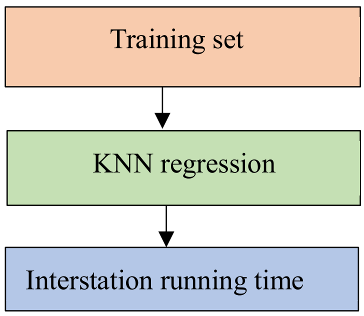

Figure 5. Interstation Running Time Prediction Model

The training set X= {x1, x2,…,x3} was input into KNN. The similarity D (formula 4) of samples was calculated using Manhattan distance, and the output value was namely the interstation running time.

$$D = |x_i - x_j| + |y_i - y_j| \tag{4}$$

2.2.3. Fusion of related sub-models

The bus stopping time prediction model and running time prediction model were introduced in 2.2.1 and 2.2.2. The prediction of bus arrival time at station was linear accumulation or nonlinear fusion of stopping time at station and interstation running time. As the bus arrival time prediction was a nonlinear problem, while LSTM showed favorable advantages in processing nonlinear time series data, LSTM was then used to fuse the outputs of the two models. The abstract graph of the mixed model is as shown in **Figure 6**:

The inputs of the whole model were the influence characteristics of interstation running time and stopping time at station. Through the two sub-models, the predicted value series R={r1,r2,…,rn} of interstation running time and predicted value series S={s1,s2,…,sn} of stopping time at station could be obtained, which were generated by iterating the two sub-models. By fusing the two models in a chronological order, the time series Xt={s1,r1,s2,r2,s3,r3,…, rn-1,sn} of bus at each downstream station on each road segment could be obtained, which was then taken as the input of LSTM to obtain an approximate output. Without consideration of emergencies, the bus arrival time predicted by the model was shortened with the bus running, so this process basically presented linear changes. Kalman achieved a significant effect in linear filtering, so a filtering layer was added to the output of LSTM, and the final model output was the bus arrival time. In this way, when the arrival time of a bus in a trip was predicted, the corresponding eigenvalue was generated through the bus position updating each time, and then substituted into the mixed model to generate an output bus arrival time, so this was a dynamic prediction process.

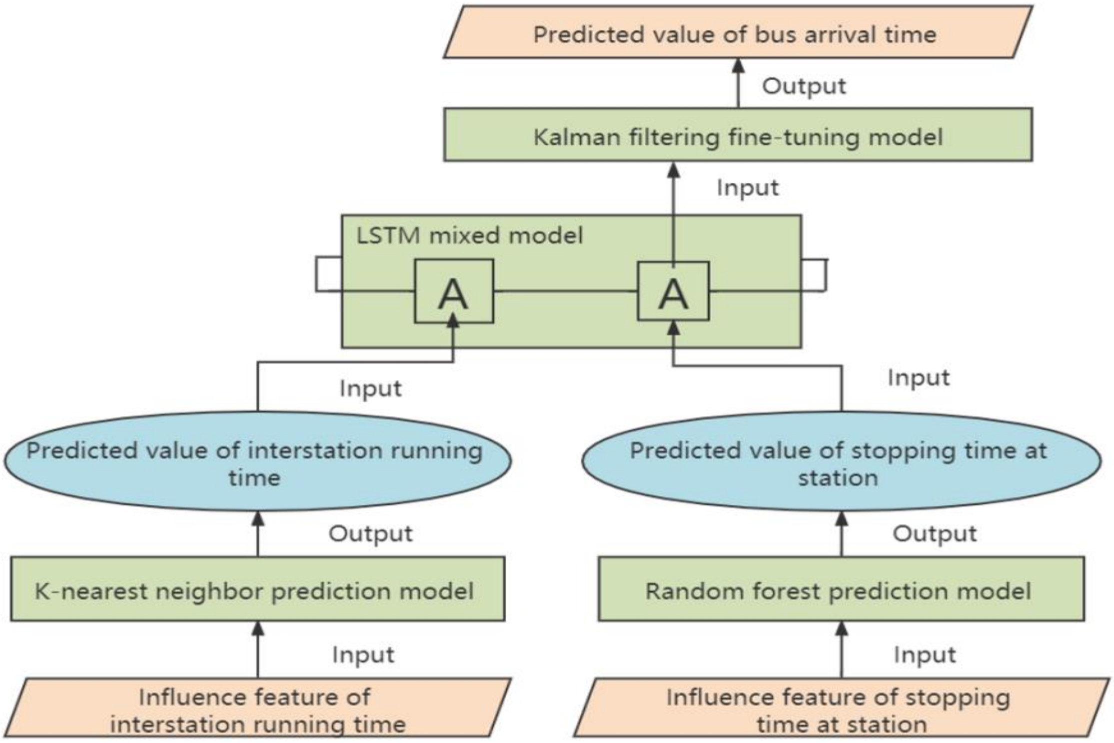

Figure 6. Abstract Graph of Mixed Model

3. Experimental analysis

The performance indexes of the proposed algorithm were analyzed using the root mean square error (RMSE) and mean absolute error (MAE) of formulas (5) and (6), where RMSE could be used to judge the model stability and MAE to discriminate its accuracy.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{m}(y_{true} - y_{pre})^2}{m}} \tag{5}$$

$$MAE = \frac{\sum_{i=1}^{m}|y_{true} - y_{pre}|}{m} \tag{6}$$

Where m denotes the sample size, y_{true} stands for the true bus arrival time, and y_{pre} is the predicted arrival time.

3.1. Comparison of stopping time prediction models at station

Five regression models were chosen as the bus stopping time models at station and then compared in the aspects of RMSE and MAE, as shown in **Figure 7**:

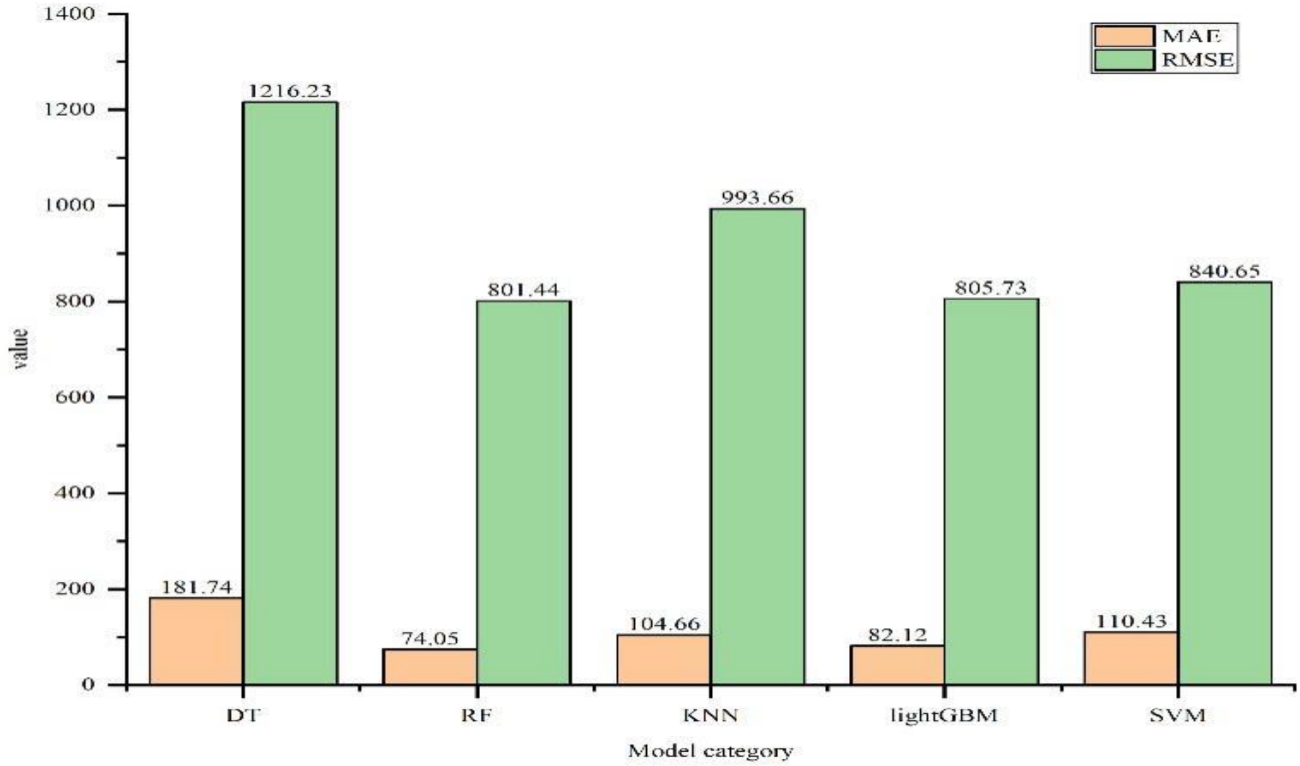

Figure 7. Model Comparison in MAE and RMSE

Figure 7 shows that, when compared to the other models, random forest and light GBM performed better in terms of accuracy and stability, implying that ensemble learning could take full advantage of each base learner's advantages to compensate for its own disadvantages and achieve a better prediction effect. Because the study object was a regression problem, the decision tree model, which was advantageous in the classification problem, performed poorly in this study. The prediction accuracy of KNN and SVM differed little, although SVM was more stable. As a result, the station stopping time was predicted using a random forest model with improved accuracy and stability.

3.2. Comparison of interstation running time prediction models

The following 5 models were also selected as the interstation running time prediction models and comparatively analyzed in RMSE and MAE, as shown in **Figure 8**.

Figure 8 shows that while the KNN regression model had a higher prediction accuracy, it did not have a significant advantage over the stability. The Light GBM and SVM models performed well in terms of stability, but not as well as the KNN model in terms of accuracy. The random forest model was sensitive to noise, and buses would unavoidably encounter traffic jams during their journey, causing the trained model to become stuck in an overfitting problem. As a result, the random forest model did not perform well in prediction. The decision tree model had the worst results. As a result, the KNN regression model was used to accurately forecast the bus interstation running duration.

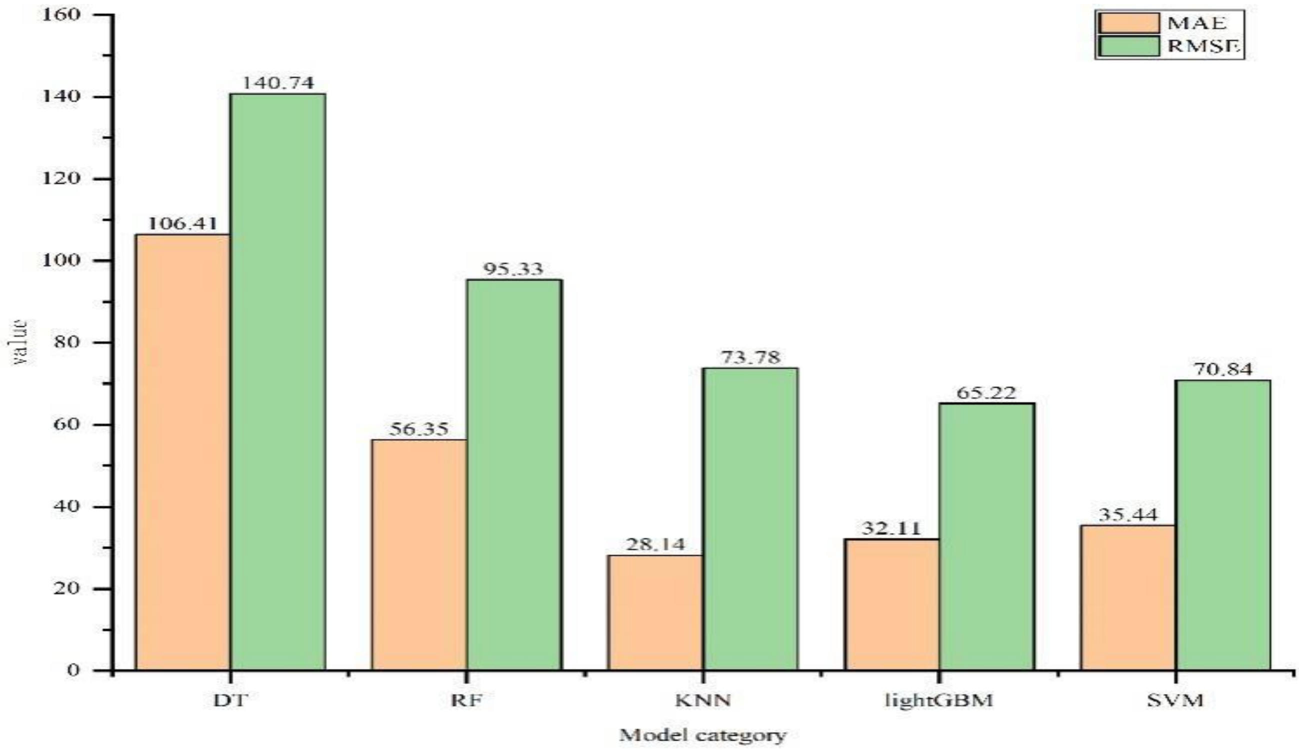

Figure 8. Comparison of RMSE and MAE Among Interstation Running Time Prediction Models

3.3. Performance comparison of mixed models

The bus stopping time prediction model at station and bus running time prediction model were already depicted in 2.2.1 and 2.2.2. The bus stopping time at each station and running time on each road segment could be acquired in an iterative way, and then linearly accumulated to obtain its arrival time. Or, the stopping time at each station and running time on each road segment could be substituted into the LSTM model to acquire the bus arrival time through nonlinear fusion. The accuracy and stability of the two methods were compared as shown in **Figure 9**:

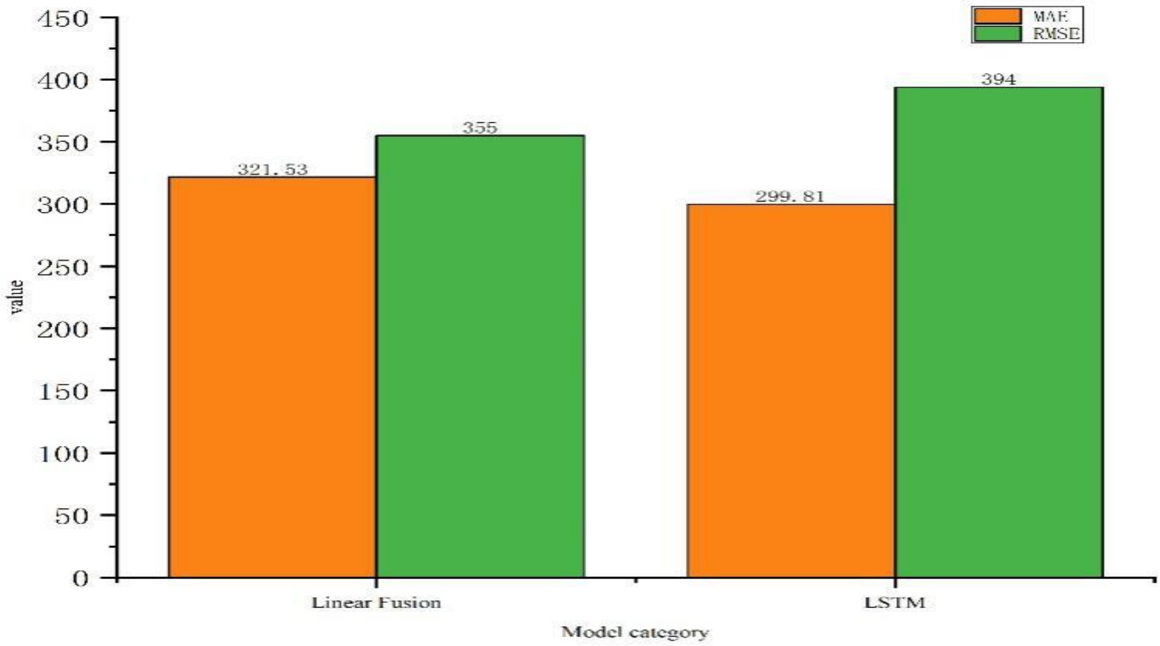

Figure 9. Comparison of RMSE and MAE Between Linear Fusion and Nonlinear Fusion

As shown in **Figure 9**, the model accuracy was improved through the nonlinear fusion of LSTM, because the bus arrival time prediction was actually a nonlinear process. Some sudden factors could not be learned simply through the linear superposition, while LSTM was a neural network model in essence, with relatively strong adaptive ability, so the prediction accuracy could be higher. Out of full consideration, LSTM nonlinear fusion was chosen in this study.

3.4. Comparison of filtering performance

In order to further eliminate the influence of abnormal data on the model, a filtering layer was added to the output of LSTM. The output of LSTM was input into the filtering layer as observed value to further optimize the model. The comparison results between the two filters are as shown in **Figure 10**:

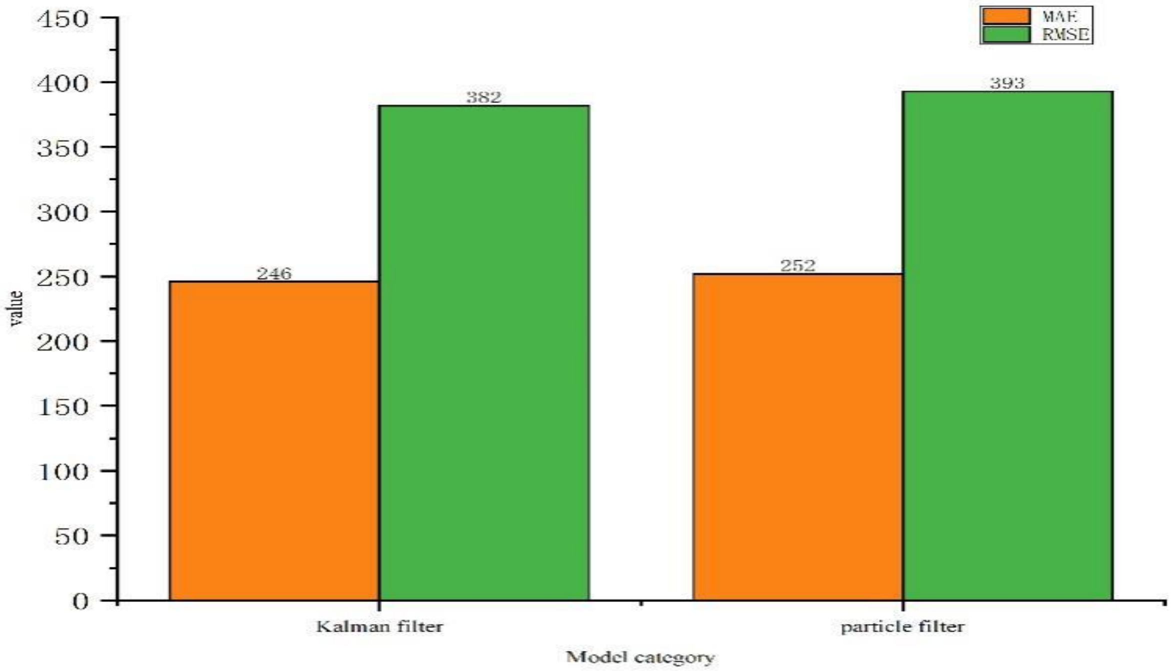

Figure 10. Comparison of RMSE and MAE Two Filtering Algorithms

It could be seen from **Figure 10** that no matter whether Kalman filtering or particle filtering was added, the model output was improved in both stability and accuracy, and the two differed little in the accuracy and stability. Given that Kalman filtering was fast, while the model required good timeliness and the prediction of arrival time was a linear process under most circumstances, Kalman filtering algorithm was chosen as the filtering layer in this study.

3.5. Model comparison

In order to embody the advantages of the proposed model, the proposed model was compared with commonly used AutoNavi and Baidu bus arrival time prediction models in the aspects of accuracy and stability as below.

As shown in **Figure 11**, the proposed mixed model had good performance in both stability and accuracy, because AutoNavi and Baidu only relied upon static data when predicting the bus arrival time and could hardly make an accurate prediction for the actual bus running status. However, the mixed model fused real-time bus data based on static data, so it accorded with the reality more and its prediction accuracy was higher.

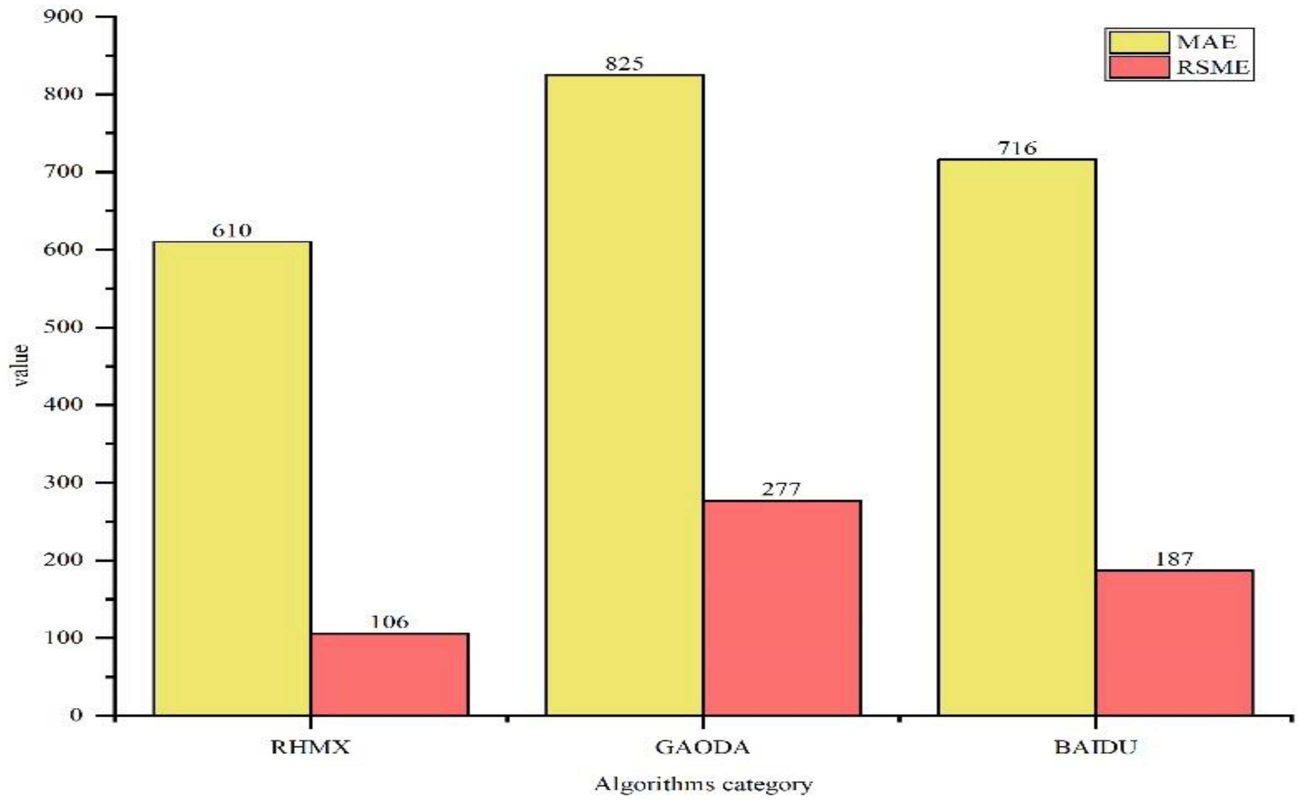

Figure 11. Comparison of RMSE and MAE Between Two Filtering Algorithms

4. Conclusion

A mixed model for forecasting bus arrival time was developed in this study. First, two sub-models were built in this model: stopping time prediction at station and interstation running time, where the former predicted the stopping time of a running bus at each downstream station in an iterative manner and the latter predicted its running time on each downstream road segment in an iterative manner. The two models might be used to predict one group of interstation running time and station halting time series data. Following that, the time series data from the two sub-models was fused using LSTM to produce an approximate bus arrival time. Finally, Kalman filtering was utilized to dynamically change the LSTM prediction results in order to avoid aberrant data influencing the anticipated value and obtain more accurate bus arrival time. This model could dynamically predict the bus arrival time based on the input data, but because the bus running time on the downstream road segment and stopping time at each station were predicted one by one iteratively, cumulative error was generated to some extent, with the cumulative error of the bus closer to the downstream station being greater. As a result, by including a residual error module in the iteration process, the error can be further decreased

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Development and Application of Methane Leakage Monitoring System for Gas Transmission Pipeline

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Abstract: Oil and gas pipeline transportation, as a relatively safe way of oil and gas transportation, undertakes most of the transportation tasks of crude oil and natural gas. Oil and gas pipeline accidents affect a wide range of consequences. Therefore, the oil and gas pipeline leakage detection is paid more and more attention. In this paper, ultra-low power methane gas sensor is selected to collect methane gas concentration in the air, and wireless network technology is used to build a wireless network sensor system with 4G function. Through the sensor distribution along the pipeline, it can intuitively and accurately judge whether there is a micro-leakage in the pipeline, and understand the diffusion situation after the leakage. The sensor system has high reliability and stability, and has high value of popularization and application.

Keywords: Oil and gas pipeline; Leak detection; Ultra-low power consumption; Methane gas sensor

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1. Introduction

With the rapid development of China's economy and society, its economic aggregate has jumped to the forefront of the world. Accordingly, the total energy consumption has also continued to grow substantially, and China has become a major energy producer and consumer [1]. The long-distance pipeline is responsible for the transportation of most crude oil and natural gas, and plays an important role in guaranteeing economic development, promoting people's livelihood, social stability and national defense construction [2]. However, the service age of the pipelines built in the 1970s is approaching or more than 50 years, and the aging is serious. Oil and gas pipeline accidents affect a wide range of consequences. Therefore, the technology of leak detection and location of large diameter and long-distance oil and gas pipeline is paid more and more attention [3].

Methane is the main component of natural gas. By detecting the small content of methane gas around the pipeline, the micro-leakage situation of the pipeline can be understood as soon as possible, and the huge loss caused by the aggravation and spread of leakage can be reduced. However, the conventional on-line methane detection device has high power consumption and is difficult to be used in the field environment with inconvenient power supply and limited communication conditions. Therefore, a low-power methane concentration sensor based on wireless Mesh network is designed in this paper. The ultra-low-power non-dispersion-infrared (NDIR) gas sensor MIPEX-04 is used to collect methane gas concentration in the air [4], through wireless Mesh network communication technology [5], and finally realized the real-time online acquisition and wireless transmission of methane concentration, and the average power consumption is less than 10mW.

The sensor is powered by a built-in high-energy lithium battery, supplemented by green energy such as temperature difference, solar energy and vibration [6]. To achieve full life cycle power supply maintenance-free. Thus, the deficiency of existing methane concentration detection sensors can be made up.

2. Design of wireless network sensor

In order to realize the low-power methane concentration sensor with wireless Mesh network communication, two parts of the system hardware and the underlying software need to be completed. The following two parts will be described in detail.

2.1. System hardware design

The current of methane measurement sensors on the market is generally large, often in the power level of hundreds of mW to several W, which is difficult to be used in low power consumption environment. MIPEX infrared absorption methane concentration sensor produced by OPTOSENSE Company of Russia is used in this paper [7], its operating power consumption is less than 3mW, greatly reducing the power consumption of the sensor.

MIPEX infrared gas sensor adopts luminescent and photodiode based on solid alloy A2B4-A2B6, which can be used for hydrocarbon detection more efficiently, and solves the problems of high temperature influence, poor stability and large volume of traditional NDIR technology in gas measurement. The MIPEX small volume sensor uses a miniature parabolic mirror with high light transmission efficiency, and a new TYPE of LED. By optimizing the radiation spectrum and special signal processing algorithm, the sensor is highly stable in the operating temperature range. The PbSe-CdSe photodiode, based on a solid film solution, is 10 times more sensitive than pyroelectric detectors and offers unparalleled temperature and long-term stability compared to earlier thermoelectric detectors. **Figure 1.** is the physical picture of MIPEX-04 series sensor.

The processor ensures the normal operation of the whole wireless sensor. Its main tasks include collecting concentration value, temperature value, battery power, wireless network networking and data transmission, and low power consumption processing. This paper uses low Power processor STM32L412 microcontroller as the system processor, which has Flex Power Control function [8], improves the flexibility of power mode management and reduces the overall power consumption of applications. The circuit of the processor is shown in **Figure 2**.

Figure 1. MIPEX-04 series sensor

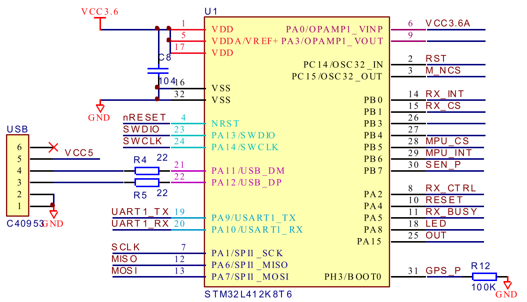

Figure 2. Main processor schematic.

Digi International Inc. (Digi) has been dedicated to the design and production of iot connected products and iot devices since the beginning of the Internet of Things. Digi International launched DigiMesh on the RF module with built-in 900MHz and 2.4GHz XBee [9].DigiMesh is an advanced peer-to-peer protocol for battery-powered networks that simplifies Mesh networks while providing advanced features such as router hibernation and support for dense networks. DigiMesh is a peer-to-peer Mesh protocol with no parent-child structure. In this way, all sensors can be put into hibernation state to save power, and at the same time, they can be used as routers and terminal devices at the same time, ensuring communication quality and effectively reducing power consumption. Its communication network topology is shown in **Figure 3.**

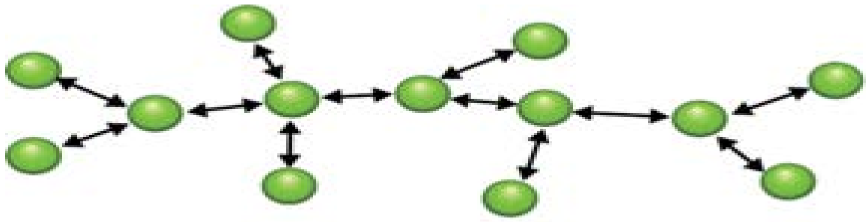

Figure 3. DigiMesh communication network topology diagram.

Through the above work, the hardware design of the sensor node is completed. **Figure 4.** is the physical picture and installation schematic diagram.

a. Physical picture of wireless network sensor b. Installation diagram

Figure 4. Sensor physical and installation diagram.

2.2. Underlying software design

In order to optimize and improve the program, the underlying software of sensor node includes Bootloader program and application program, which realizes IAP function through function pointer program jump, redirection interrupt direction table and change program download address. In order to realize the Bootloader function, the ROM size of the processor is reasonably partitioned into the Flash space. The Flash partition and its related description are shown in **Table 1.**

Table 1. Flash partition table

Starting address	The final address	The size	instructions
0x8000000	0x8003FFF	16KB	Bootloader program area, reset startup
0x8004000	0x80217FF	118KB	Application area, Bootloader jump start procedure
0x8021800	0x803EFFF	118KB	New application area, temporarily store the new firmware when upgrading
0x803F000	0x803F7FF	2KB	Firmware upgrade data, store the upgrade status
0x803F800	0x803FFFF	2KB	Application data, which stores configureuration parameters

Wireless sensor nodes and gateways are designed based on FreeRTOS [10]. FreeRTOS is an open source and tailorable multi-task real-time operating system. FreeRTOS has no limit on the number of system tasks and supports both priority scheduling algorithms and rotation scheduling algorithms.

The application program design mainly uses the task scheduling function of FreeRTOS and the low-power Tickless mode to achieve a short-term low-power state during a variety of sensor data collection, data communication and idle tasks.

3. Network platform design

In order to realize real-time data monitoring and alarm, the network platform needs to acquire real-time data of each sensor node and conduct data analysis and processing. Therefore, the network platform is divided into data acquisition platform and data analysis platform. The design of these two parts is described in detail below.

3.1. Design of data acquisition platform

The data collection platform focuses on data collection and is composed of Server, gateway and each sensor node. It belongs to CS architecture (Client/Server). Each sensor node communicates with the Server through the gateway using HTTP protocol, and can obtain configuration information for updating and real-time uploading of field data. Its communication structure is shown in **Figure 5**.

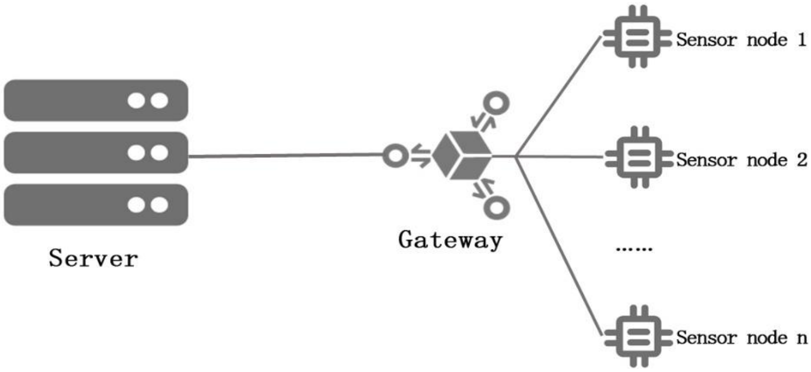

Figure 5. Network communication structure diagram.

Since the HTTP protocol is transmitted in plaintext during data transmission, there is a risk of leakage of sensitive information, so we use encryption algorithm to encrypt data before transmission. In the selection of encryption algorithm, we compare the advantages and disadvantages of DES, AES and RSA encryption algorithms and finally choose AES algorithm. Compared with DES algorithm, AES algorithm has higher security and operation speed. Compared with RSA, RSA has higher security intensity, but it also puts more pressure on the server and low-power sensors when a large amount of data is transferred.

For the convenience of data analysis platform for data analysis and processing, we store the latest data of each node in Redis [11]. In memory database to facilitate quick query, when there is a change in a certain kind of data collected by the node, the data in Redis will be updated, otherwise only the timestamp of the data will be updated; In addition, each collected node data is written to RabbitMQ [12]. In message queues, the data analysis platform processes and decides which data needs to be stored persistently.

3.2. Data analysis platform design

The data analysis platform analyzes and processes the collected data, and presents the analysis results. It belongs to THE BS architecture (Browser/Server). In addition, to minimize the strain on the server, we put some of the data calculation in the browser side.

To monitor whether each node is offline, we use the heartbeat mechanism for detection. Each node periodically uploads the collected data to the data collection platform. The data analysis platform analyzes the time of the data in the message queue. If no new data is received within the specified time, the node is considered offline. According to the corresponding algorithm to analyze the gas concentration, environmental temperature and other data, to judge whether there is abnormal environment node.

In most of the time, the data collected by a node is unchanged. If persistent storage is carried out for each node, the amount of data stored by the server will also increase sharply when the number of sensor nodes is large. Therefore, in order to reduce unnecessary data storage, we only carry out persistent storage when the data changes, and store the time when each piece of data is received. In this way, it is easy to infer what kind of data is collected during this period from the time difference between the two pieces of data, which can greatly reduce the amount of data to be stored persistently.

4. Field application

Through a long time of field application, it can be seen from the monitoring data of the network server that the system has strong real-time performance, stable operation and high reliability. **Figure 6.** and **Figure 7.** show the methane gas concentration data curve and temperature data curve recorded by server monitoring respectively.

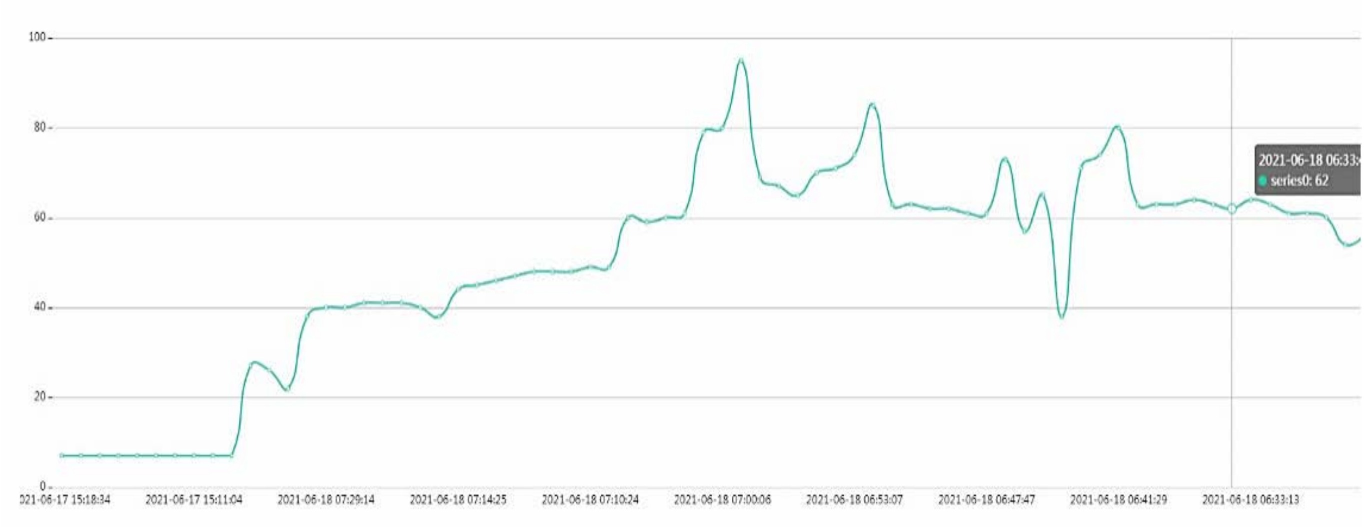

Figure 6. Monitor the methane gas concentration data curve.

Figure 7. Monitoring temperature data curve.

5. Conclusion

In order to make up for the disadvantages of conventional methane gas concentration monitoring instruments, such as large power consumption, inconvenient layout and poor communication, this paper designs a methane concentration sensor that can use independent power supply in the field environment. The sensor realizes real-time monitoring and transmission of methane concentration under low power consumption based on wireless Mesh network. The long-term application in the field shows that the sensor has the advantages of low power consumption, stable operation, simple structure and convenient installation. It can not only be used in gas pipeline leakage monitoring, but also in oil and gas, chemical industry, coal mine and other high-risk environments. It has great market application and promotion value.

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Disclosure statement

The author declares no conflict of interest.

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Hospital Indoor Navigation System Based on QR Codes

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Abstract: With the continuous increase in China's population, the number of people visiting hospitals are also increasing. In order to meet the needs of patients, hospitals are expanding their scale, and departments are becoming more and more sophisticated. While improving the quality of medical services, it has become more difficult for patients to seek medical consultation. In order to improve the quality of medical services, a indoor navigation system based on QR code has been designed for hospitals, which realizes indoor navigation by scanning a QR code. This low-cost technology has accurate positioning, which brings convenience in locating and navigating departments.

Keywords: QR code; Indoor navigation; WeChat platform

Publication date: November 2021; ***Online publication:*** November 30, 2021

1. Introduction

1.1. Research background

With the continuous progress of science and technology, the reform of medical and health system, as well as the transformation of the mode of hospital service, hospitals are constantly developing in the direction of convenience and fast information. This means that the number of patients is growing. At the same time, hospitals are also expanding, the medical specialty is subdivided, the division of labor of various clinical specialties is more detailed, the setting of departments is more refined, and many new hospitals are progressing. The design of a reasonable hospital navigation system can help patients and visitors find relevant departments quickly, efficiently, and accurately, reduce medical difficulty, as well as improve their medical service experience. This has become the focus of attention.

The outpatient volume of general hospitals is generally large. For patients visiting the hospital for the first time, facing the complex and strange hospital environment [1], a considerable amount of time is needed for them to find the department they wish to go to. For example, Nanjing Gulou Hospital has 32 clinical departments alone. For large local hospitals, it is not uncommon for the building area of a single building to reach or even exceed 500,000 square meters. Without reliable guidance, it is difficult for patients to find departments, clinics, and examination rooms in such a huge building. It is easy to fall into "turbulence" and waste valuable time, and in worst case scenario, miss the best treatment time, which will greatly aggravate the anxiety of patients and their families as well as the tension between doctors and patients.

The classification of departments not only increases the burden on patients, but also reduces the efficiency of doctors, and objectively increases the possibility of tension between doctors and patients. In view of this situation, there are two traditional medical guidance methods. The first is to set up a medical guidance platform, but because the medical guidance platform is fixed, it is not convenient for patients to find it in real time. The second is to set up a plane guidance diagram, but the amount of information storage is limited; hence, with poor real-time sense, it is not easy to identify the direction.

With the popularization and development of mobile network, mobile phones have become an indispensable communication tool for people's life, work, study, and communication, and WeChat has undertaken the leading role of mobile phone software applications. By the end of 2018, the average daily number of WeChat transmissions was 38 billion, with users in more than 200 countries and nearly 20 languages around the world. As an important part of WeChat, WeChat public platform has quickly penetrated into all walks of life with various advantages, including convenience, short development time, and low cost. The use of WeChat public platform is not only convenient and timely, but also widely applicable [1].

QR codes have a large amount of information storage, a wide range of coding, strong error correction function, high reliability, and low production cost compared with other types of technologies. Therefore, saving a location information into a QR code can improve the feasibility of the system.

With this technology, the department information is bound to the QR code. Users can then easily scan these QR codes for positioning. With the navigation function, the nearest QR code can be used to locate the location of the person and find one's destination. The system can accurately locate all departments of the hospital. This technology easily guides patients around the hospital and improves their satisfaction [2].

1.2. Steps and contents

QR codes can be placed at eye-catching areas in each building and department. The specific positions and other information can also be stored in QR codes.

In order to realize indoor department navigation on the basis of accurate positioning, the corresponding information on the department location of each QR code needs to be stored in the database. When users have determined their own location coordinates, they can then scan the nearest QR code. After determining the target location information, the system retrieves the route map stored in the database in advance. Through the intuitive display of WeChat client, users can then find the destination according to the route shown in the map [3].

There are several steps in the development process of the system.

1.2.1. Preparations before development

(1) Investigate and analyze the hospital's treatment business process and user needs.
(2) Apply for WeChat public platform account and external network server that needs data interaction to build the environment for system operation.

1.2.2. Demand analysis and design

This step mainly includes the following aspects: system demand side analysis, functional demand analysis, system interface design, WeChat client design, background database design, etc.

1.2.3. System design and implementation

Several frameworks and technologies are used in the design and implementation of the system, including Bootstrap, WeChat, JavaScript-SDK interface, JavaScript chart library, Highcharts, amCharts, h-ui front-end framework, jQuery, and indoor positioning technology (IPS).

2. System design

2.1. Overall design of the system

In the WeChat public platform development document, when creating a custom menu, two interfaces are required, both of which are HTTP requests. First, encapsulate the menu. The request method is as follows:

(1) receive HTTP request layer – handle HTTP request function, different types of messages, and messages in XML format;
(2) distribution layer – achieve scalability and expand the system at any time;
(3) combine with business processing and data logic layer.

The system requires the user to confirm the user's current location by scanning the nearest QR code through the QR code scanning applet. During navigation, the navigation route is planned according to the starting point and destination entered by the user, and the route map is fed back to the user to facilitate the user to find the destination.

2.2. Related algorithm design

2.2.1. Determine the navigation direction

Use the vector cross product to determine whether it is counterclockwise or clockwise, so as to determine whether the navigation direction is left or right.

Let vector p = (x1, Y1), q = (X2, Y2), and r = (X3, Y3); calculate (x2-x1) (y3-y1) - (y2-y1) (x3-x1) according to vector p, vector q, and vector r; then, determine the size of the result. If it is greater than 0, turn clockwise to the right; if it is less than 0, turn counterclockwise to the left; if it is equal to 0, it is collinear, which means, it may be straight forward or backward.

2.2.2. Obtain track coordinates

As shown in **Figure 1**, assuming that people walk 1.4 meters per second, it is possible to determine the coordinates of B, C, and P2 according to each second. Then, using the principle of similar triangles, the coordinates of A can be determined.

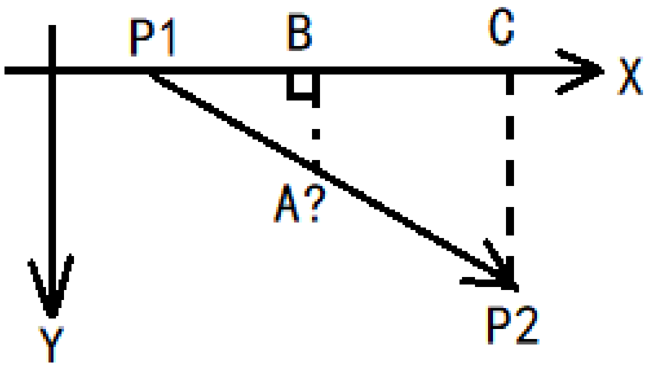

Figure 1. Obtaining the coordinates on the trajectory line

3. Implementation of the system

3.1. Realization of user interaction function

(1) Upon receiving the message sent by the user, call the encapsulated parseXML() method to parse the request message and obtain the message type MsgType to determine the message type sent by the user. Message types include subscribe, unsubscribe, click, etc.
(2) Determine whether the type of MsgType message is a push type event. If the two types are the same, continue to ascertain whether the event type is a subscribe type. If yes, push the text message to the user; if not, send an error message.
(3) If the event type is equal to the user-defined menu item click event, determine which option the user clicks according to the value of the key. If the event attribute key value is the same as the key value of the menu creation, create a graphic message, and reply the user; otherwise, send an error message.
(4) Finally, the message object is encapsulated and transformed into the corresponding XML format.

3.2. Realization of indoor positioning and navigation function

(1) Realization of "location confirmation" function

After clicking "location confirmation," the user's current location information is determined, which can realize the scanning function. When the user clicks "get current location," the WeChat scanning interface function is called, and the text information is obtained from the QR code; that is, the user's current location information.

(2) Realization of "visit navigation" function

With the "visit navigation" function, the code can be scanned to confirm the departure, and the destination can then be entered to determine the starting point of the navigation. With that, the "visit navigation" function is realized, as shown in **Figure 2**.

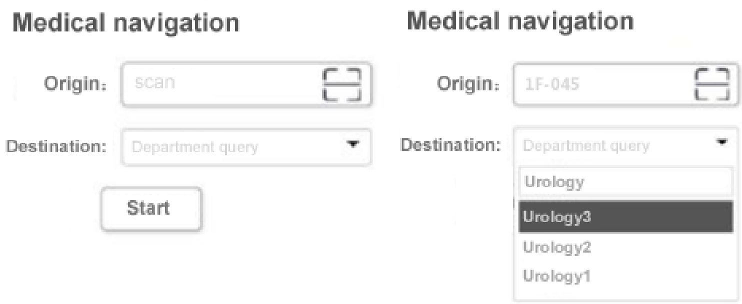

Figure 2. Visit navigation

The departure and destination in the navigation is from "wound care room" to "urology," respectively. The navigation diagram is shown in **Figure 3**.

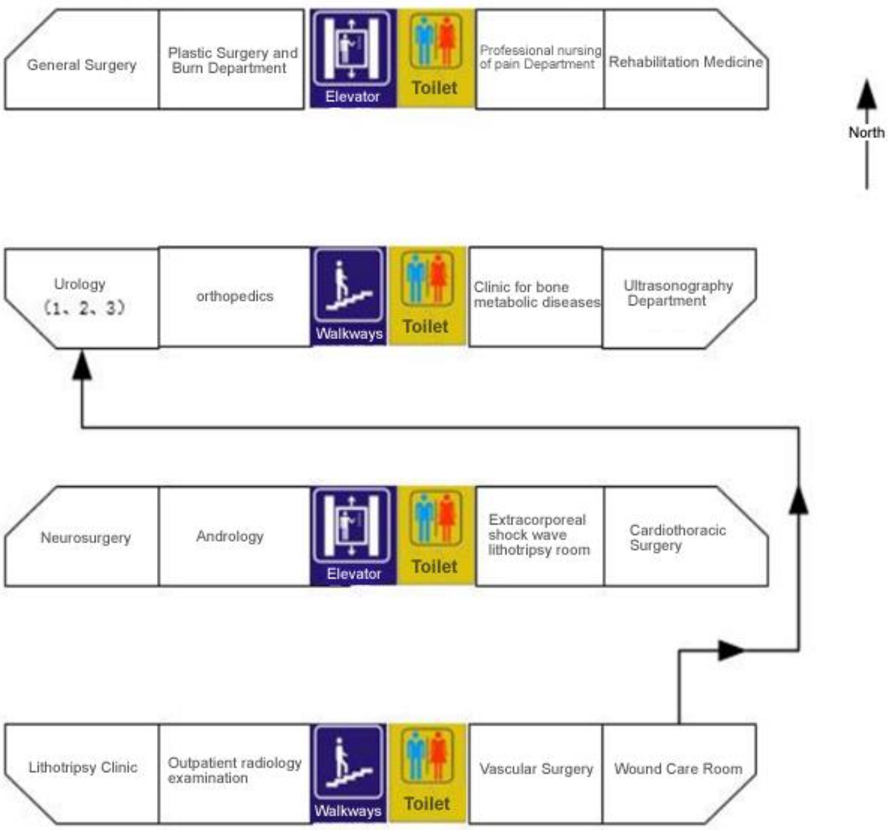

Figure 3. Navigation diagram

(3) Realization of “floor guidance” function

This function is mainly used to guide users to obtain the overall layout information of the hospital. The building submenu can be clicked to push the specific department information of each floor of the selected department building to the user.

4. Conclusion

The hospital indoor navigation system based on WeChat can realize the indoor navigation between different departments in a hospital. Users can locate and navigate in real time through the QR code using their mobile phones and other handheld terminals, which is convenient to guide users to find relevant departments.

The core problem solved in this paper is the use of WeChat public platform to scan QR codes for location confirmation. Upon location confirmation and entering the destination, navigation will then be given to the user. Further research and design can be centered in this area in the future.

Disclosure statement

The author declares no conflict of interest.

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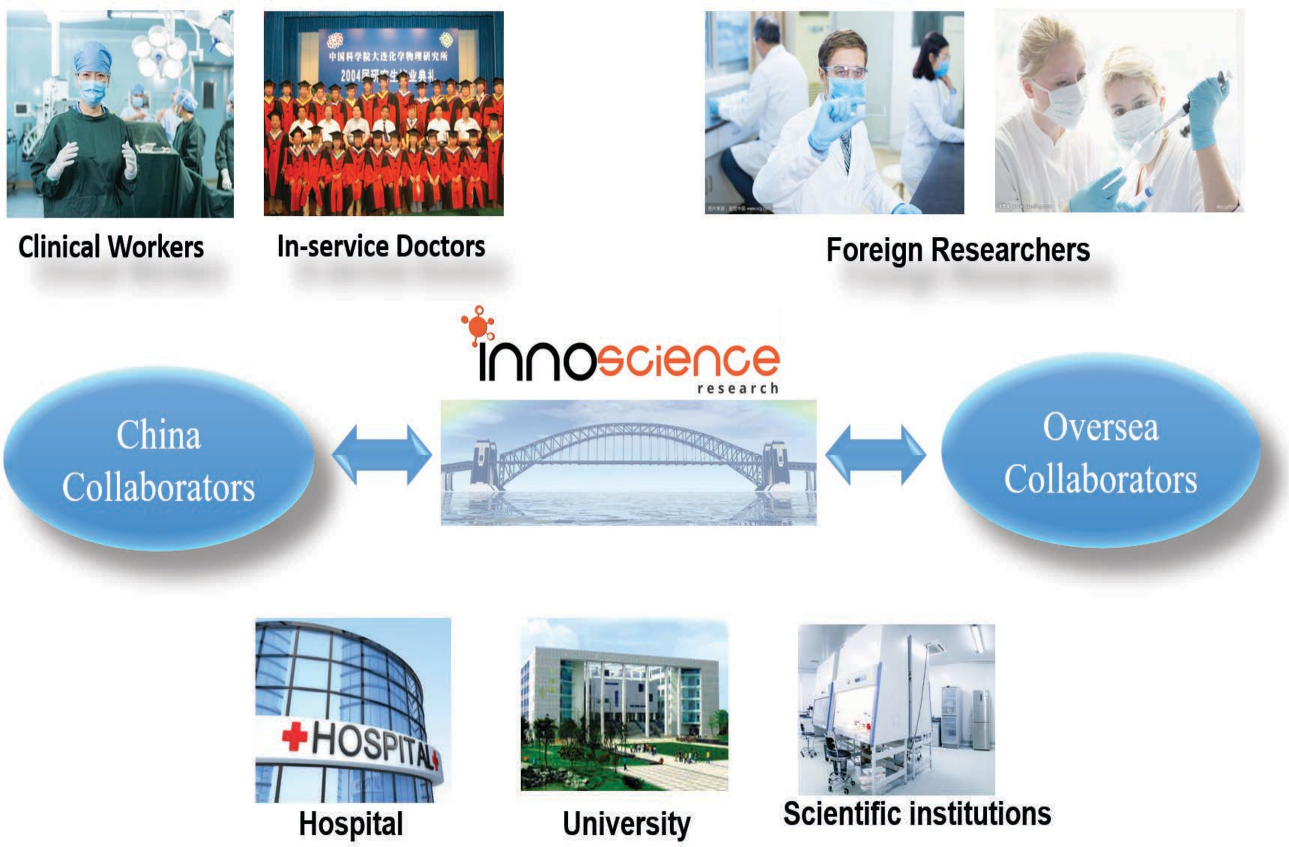

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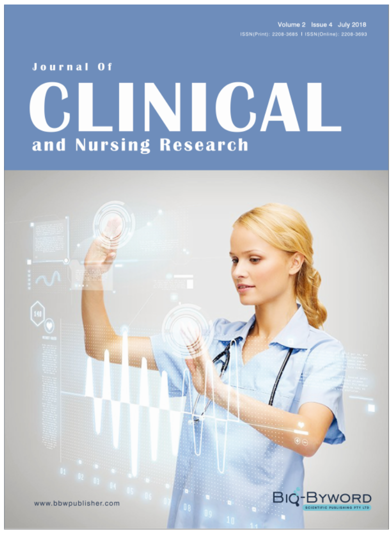

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