Design of Iot Data Acquisition System Based on Neural Network Combined with STM32 Microcontroller

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Abstract. Aiming at the low efficiency and high power consumption of data acquisition in the Internet of Things, a data acquisition system based on the combination of neural network and STM32 microcontroller is designed. In the control module, according to the system functional design and performance requirements, the STM32F103C8T6 minimum system module is used as the control core of the system. The data acquisition terminal adopts the baseplate + core board structure, and is composed of high-speed data acquisition module, AT91SAM9X25 platform and various expansion function modules. Eight types of environmental data sensor modules are used to build sensor modules. The k-means convolution neural network is used to realize the data classification of the Internet of Things, and the design of the data classification module is completed. The performance of the system is tested. The test results show that the system can realize the real-time collection of indoor environmental data, the communication rate is higher than 80 mbps, and the power consumption of the data acquisition terminal is low.

Keywords: Neural Network · STM32 Microcontroller · Arm Chip · Internet of Things · Data Acquisition System

1 Introduction

In recent years, the rapid development of the Internet of Things industry has become the strategic commanding point of a new round of economic and technological development in the world. There are traditional electrical appliance manufacturers, as well as some Internet companies and start-up companies; the second is the control center, such as Ali Xiaozhi launched by Alibaba, which integrates many APPs; the third is the ecosystem, the main model currently emerging is intelligent module + control center + cloud service, Such as Xiaomi, Haier, Ali, Tencent, Baidu, etc.; the fourth is the operating system. Currently, Ali YumOS, Tencent's TOS, 3600S, etc. are promoted to the Internet of Things operating system [1]. The driving role of the Internet of Things in manufacturing, operation, application and other related industrial chains is becoming more and more prominent. At the same time, with the further upgrading and improvement of the Internet of Things industry standards, the Internet of Things will extend in the direction of

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clustering and collaboration, further strengthen industrial cooperation, and accelerate the penetration and integration of the Internet of Things in related industries and fields; further build an independent innovation system, enhance the core competitiveness of the industry; at the same time, give full play to the market advantages, cultivate and expand the Internet of Things industry, and form an all-round integrated global Internet of Things architecture system.

At present, the widespread popularity of the Internet of Things has been integrated into all aspects of people's daily production and life. From the perspective of structural layering, the Internet of Things can be expressed as a three-layer architecture consisting of a perception layer for comprehensive perception, a network layer for reliable transmission, and an application layer for intelligent processing. Various emerging sensing technologies such as surveillance cameras, face recognition technology, and global positioning systems constitute the application terminals of the Internet of Things. Since the standards for sensor device acquisition are not uniform, an intelligent terminal acquisition system is needed to perform unified data acquisition, control, processing, and transmission. Based on this background, the Internet of Things data acquisition system is researched.

Reference [2] proposes a NB-IoT wireless sensor IoT data acquisition system. The main controller is designed and implemented by the STM32L476 low-power microprocessor. The SHT30 sensor is used to collect temperature and humidity data, and the 433 MHz wireless communication module is used to realize the data communication between the node and the coordinator. The coordinator uses the NB-IoT Internet of Things technology to realize the For the docking of the platform, the coordinator and the sensor nodes adopt a star-shaped ad hoc network to realize the upload and delivery of data and commands between the sensor nodes and the IoT platform. Reference [3] designed a multi-channel data acquisition system based on the Internet of Things. Collect data through temperature and humidity, carbon monoxide, carbon dioxide and dust collection modules, send the data to the coordinator node through the wireless network, and store, analyze and process the data at the same time. The coordinator node transmits data to the client through the cloud server for monitoring.

Under the above background, this paper proposes the design of IoT data acquisition system based on neural network combined with STM32 microcontroller. STM32F103C8T6 minimum system module is used as the control core of the Internet of Things data acquisition system to improve the reliability of the Internet of Things data acquisition system. The data acquisition terminal adopts the baseplate + core board structure, and is composed of high-speed data acquisition module, AT91SAM9X25 platform and various expansion function modules. Eight types of environmental data sensor modules are designed to build sensor modules. The k-means convolution neural network is used to realize the data classification of the Internet of Things, and the design of the data classification module is completed.

2 IoT Data Acquisition System Design

2.1 Control Module Design

In the control module, according to the system function design and performance requirements, the STM32F103C8T6 minimum system module is used as the control core of the system. It is mainly composed of STM32F103C8T6 single-chip microcomputer, clock circuit, reset circuit, power supply, etc. With the peripheral design circuit of the system, it can The information collected by the sensor is converted into information that can be identified and processed by itself.

The STM32 series of microcontrollers are 32-bit microcontrollers with very powerful functions developed by ARM and based on the ARM Cortex-M core. The STM32F103 series of microcontrollers use a 32-bit Cortex-M3 core with a maximum CPU speed of 72 MHz. This product family has 16 KB−1 MB Flash, various control peripherals, USB full-speed interface and CAN. It has high integration, good reliability, rich command system, low power consumption, serial programming, and very cheap price. According to the relevant experimental data, the STM32 MCU not only consumes less power, but also has significantly better performance than the MSP430 and C51 series MCUs in the processing speed, floating-point operations and environments that require complex operations. In view of the many advantages of STM32F103 series single-chip microcomputer, combined with system design function and performance requirements, STM32F103C8T6 single-chip microcomputer is used as the core processor. The main features of the STM32F103 series of microcontrollers are shown in Table 1.

In STM32F103C8T6, the main function of the system clock circuit is to provide the rhythm, and this system clock circuit selects an 8M crystal oscillator. The role of the reset circuit is to restore the system to its initial state. The development board used in this system is a low-level reset. When the button is floating, the RESET input is high level; when the button is pressed, the RESET pin input is low level, thus the circuit is reset [4].

Three different startup modes can be selected by setting the BOOT[1:0] pins. The startup modes are shown in Table 2.

Use C language to develop the software function program of STM32 microcontroller. This system uses KeilUvision5 MDK software to write C language program code. Keil Uvision5 MDK software provides a complete development environment for devices based on Cortex-M, Cortex-R4, ARM7, and ARM9 processors. It is specially designed for microcontroller applications. Most demanding embedded applications. Keil Uvision5 MDK includes all software system development functions such as program writing, compiling, debugging, etc. It can not only write the code, but also check the right or wrong of its programming, check the functionality of the code through simulation debugging, and finally pass the downloader and microcontroller. The system can be directly connected and can be debugged online, and can perform functional testing through physical objects.

After the system software is compiled, compile the designed program to generate the target file.hex, download it to the STM32F103C8T6 single-chip microcomputer through the programmer, then insert the single-chip microcomputer into the socket of the PCB board, and connect the power supply to the produced object, and the program download

Table 1. Main features of STM32F103 series microcontrollers

Serial number	project	Main characteristics
1	Arm32-bit Cortex-M3 CPU core	The maximum operating frequency is 72 MHz; The memory access performance in the 0 wait state is 1.25 dmips/mhz (dhrystone2.1); One cycle multiplication and hardware division
2	storage	64 or 128 KB flash memory; 20 KB SRAM
3	DMA	7-channel DMA controller; Supported peripherals: timer, ADC, SPI, I2C
4	Up to 80 fast I/O ports	26/37/51/80 multifunctional bidirectional 5 V compatible I/O ports, all I/O ports can be mapped to 16 external interrupts
5	Debugging mode	Serial line debugging (SWD) and JTAG interface
6	Two 12 bit analog-to-digital converters, l μ S conversion time (up to 16 channels)	Conversion range: 0 to 3.6 V dual sampling and holding capacity temperature sensor

Table 2. Boot Mode Table

Serial number	Startup mode	Select pin	
		BOOTO	BOOT1
1	Main flash memory	1	0
2	System memory	1	1
3	Built in SRAM	0	1

can be completed [5]. During the download process, if the program download fails, it is necessary to verify the serial port and the microcontroller. Whether the model selection is correct; when confirming that the previous sequence is correct, you need to power off and then power on the microcontroller to download. Software debugging needs to be combined with hardware. The debugging steps are roughly as follows:

(1) Open the Keil Uvision5 MDK software, create a “New Vision Project”, determine the type of the single-chip microcomputer chip, and complete the program code writing; or, select the program code that has been written;
(2) Complete the program code compilation through the “Build Target” function of the Keil Uvision5 MDK software;
(3) Program code error correction, compile repeatedly until the error is 0, use the “Debug” function to simulate and debug;

(4) Through the "Options for Target" function in the "Project" of the Keil Uvision5 MDK software, check "Create hex file" in the "Output" column, and click "Compile, Build, Rebuild" in the software toolbar in turn. The software generates the.hex target file, and burns the.hex file into the STM32 microcontroller to check the operation;
(5) Confirm whether the software function meets the design requirements, otherwise return to the first step to write the code.

2.2 Design of Data Acquisition Terminal

The data acquisition terminal adopts the structure of base plate + core board, which can maximize the scalability and versatility of the system. It is mainly composed of high-speed data acquisition module, AT91SAM9X25 platform, and various expansion function modules. According to different application scenarios, the backplane, sensor, and USB device can be replaced, which reduces the project development cycle and has strong flexibility [6]. The high-speed data acquisition module is composed of high-performance sampling chips and FPGA chips, which are responsible for high-speed data acquisition; the AT91SAM9X25 platform is responsible for data processing and the realization of other extended functions.

In order to collect external environmental data at different rates, a variety of interfaces are designed in the data collection part. For external data with high-speed instantaneous fluctuation, high-speed data acquisition module is used for high-speed sampling; for external data and sensor data of general rate, data acquisition is performed directly, and external digital signals are received through SPI interface, RS485 interface, and general GPIO port. And through the on-chip multi-channel ADC, the analog/digital signal output by the sensor can be directly collected.

The core part of data processing is composed of AT91SAM9 $\times$ 25 platform, the main processor is ARM926EJ-S chip, the main frequency is 400 MHz, 128 M DDR2, 256 M NANDFLAS, the platform has high-speed USB2.0 interface, 10/100 Mbps Ethernet MAC, two HS SD Card/SDIO/MMC interface, USART, SPI, I2S, multiple TWIs and 10-bit ADC, the platform is plugged into the base through pin headers.

The data processing part controls each IO port, communication module, storage module, and video monitoring module of the terminal to meet the needs of terminal expansion functions. The system frame of the terminal data processing part is shown in Fig. 1.

Digital signal interface: The system can communicate with any sensor with an RS485 interface, or read external environmental data to the system through a general-purpose GPIO port.

Communication module: The user can view the collected data in real time remotely or locally through the wired Ethernet port, 4G MODEM, and wireless WIFI interface. It is also convenient for users to transmit the collected data to the data management center in a wired or wireless manner [7].

Video Surveillance Module: Real-time display of external environmental conditions through a USB camera.

Data storage module: realizes the local cache of data, supports storage in mobile devices or flash.

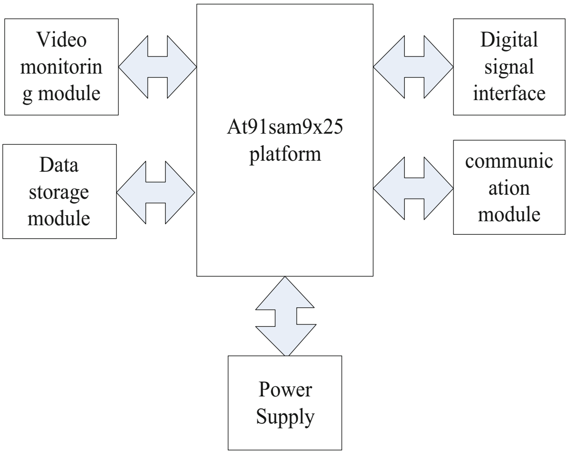

Fig. 1. System framework of terminal data processing part

The AT91SAM9 × 25 platform contains 12 channels of 10-bit AD sampling channels, which can meet some low-speed external environmental data acquisition, but for the data acquisition requirements of high-speed transient, large fluctuation and high acquisition accuracy, it is necessary to use the data acquisition part. High-speed AD data acquisition module. It can be seen from the analysis of the data collection principle that for high-speed external environment data, the real-time sampling resolution of the data needs to be improved, and the sampling interval must be shortened, and the collection points must be maintained and stored [8].

The data collection terminal not only needs to complete the real-time collection of data, but also needs to cache the collected data locally for subsequent further data processing. This terminal is designed to realize large-capacity storage of collected data through SD card and U disk, which is convenient for data export. It can also be saved to memory FLASH. SD card is a new generation of multimedia memory card, which has the characteristics of high-speed data storage, safe plugging and unplugging under power, and safe data writing. Compatible with MMC card, the interface that supports inserting SD card also supports inserting MMC card.

The USB interface has the characteristics of high speed, two-way synchronous transmission, and pluggability, which is convenient for the realization of terminal expansion auxiliary functions. The data acquisition terminal expands the video monitoring function, wireless WIFI function, 4G dial-up Internet function, U disk and so on through the USB interface. The data acquisition terminal realizes the wireless access to the IoT cloud platform for the collected data, using WIFI based on USBWiFi module for short distances; using 4G modem based on USB4G cellular module for long distances. The WIFI module adopts Leike Leike's NW362, which is based on RTL8192 chip, supports USB2.0, transmits power of 20 dBm, wireless connection rate up to 300 Mbps, supports IEEE 802.11b/g/n wireless standard, and supports multiple data encryption methods, WPA security mechanism. The cellular module uses SIMTECH's SIM7100C, SIM7100C has a USB interface, supports a variety of mobile frequency bands, and supports dial-up Internet data services and SMS services.

2.3 Sensor Module Design

As the nerve endings of the Internet of Things, sensors are an important element for human beings to fully perceive the natural world. The wide-scale application of various sensors is a necessary basic condition for the Internet of Things. Sensors can be divided into humidity sensors, magnetic sensors, gas sensors, chemical sensors, etc. according to their applications.

The system adopts eight types of environmental data sensor modules, namely: DS18B20 digital temperature sensor module, DHT11 digital temperature and humidity sensor module, MQ-2 smoke sensor module, MQ-5 LPG sensor module, MQ-7 carbon monoxide sensor module, MQ-137 ammonia gas sensor module, MQ-138 aldol gas sensor module, MG-811 carbon dioxide sensor module [9].

DS18B20 digital temperature sensor is launched by DALLAS company in the United States. It is an excellent digital temperature sensor and has the following advantages: high accuracy, 12-bit binary conversion result, ± 0.5 °C accuracy and 0.0625 °C resolution; DHT11 sensor has The following features: humidity accuracy $+ -5\%$RH, relative humidity and temperature measurement; full calibration, digital output; excellent long-term stability; no additional components required; long signal transmission distance, up to about 20 m; ultra-low energy consumption; 4-pin mount; fully interchangeable; can be used in harsh environments; MQ-2 smoke sensor: This smoke sensor is mainly used for smoke detection caused by various gas leaks. It has the following characteristics: can accurately measure the smoke concentration caused by liquefied gas, natural gas and other gases; has good sensitivity; has a long service life and reliable stability; fast response and recovery characteristics; can be used in homes or factories; MQ -5 Liquefied petroleum gas sensor: It is suitable for the monitoring device of liquefied gas, natural gas and coal gas in household or industry. It has the following characteristics: good sensitivity to liquefied gas, natural gas and city gas; almost no response to ethanol and smoke; fast response and recovery characteristics; long service life and reliable stability; simple test circuit; MQ-7 Carbon monoxide sensor: mainly used for the detection of carbon monoxide and carbon monoxide-like gases. It can be used in enterprise production environment or ordinary home environment. It has the following characteristics: high sensitivity; long service life; strong stability; MQ-137 ammonia gas sensor: a harmful gas detection device suitable for households, factories, and atmospheric environments, and is suitable for ammonia vapor detection. Ammonia gas sensor has the following characteristics: fast response recovery and high sensitivity; simple test circuit; long-term working stability; MQ-138 aldol gas sensor: commonly used for detection of aldol gas. It has the following characteristics: wide detection range; fast response recovery and high sensitivity; long-term working stability; simple test circuit; MG-811 carbon dioxide sensor: carbon dioxide detection device suitable for home and business. It is suitable for the detection of carbon dioxide concentration. The carbon dioxide gas sensor has the following characteristics: good sensitivity and selectivity to carbon dioxide; under normal circumstances, changes in temperature and humidity have little effect on it; good stability and reproducibility.

The range data of the eight types of environmental data sensor modules are shown in Table 3.

Table 3. Range data of environmental data sensor module

Serial number	sensor	Sensor type	range
1	DS18B20	Digital temperature sensor	Temperature range: - 55 °C–+ 115 °C
2	DHT11	Digital temperature and humidity sensor	Humidity range: 20–80% RH
3	MQ-2	Smoke sensor	Smoke range: 300−20000 ppm
4	MQ-5	LPG sensor	Liquefied gas, natural gas, gas range 500−6000 ppm
5	MQ-7	Carbon monoxide sensor	CO concentration range: 5−1200 ppm
6	MQ-137	Ammonia sensor	Ammonia gas range: 15−350 ppm
7	MQ-138	Aldehyde, ketone and alcohol sensors	Formaldehyde (2−20), acetone (5−500), methanol (2−200) unit: ppm
8	MG-811	Carbon dioxide sensor	CO2 range (2 to 20000 ppm)

Environmental data sensors perform their respective duties and monitor the corresponding environmental values in the surrounding environment. Due to the various data formats (units, value ranges) it collects, it needs a "command" to manage it, resulting in a sink node, that is, a coordination and management node. According to the derived purpose, the coordination management node mainly aggregates the data of eight environmental data sensors, formats it, and transmits data with the TQ6410 gateway. The sink node used is STM32W108.

2.4 Data Classification Module

The data classification module is designed based on neural network, and k-means convolutional neural network is used to implement IoT data classification. The design of k-means convolutional neural network is as follows: K-means algorithm is a vector quantization method derived from signal processing, and now it is more popular in the field of machine learning as a clustering algorithm. The purpose of the K-means algorithm is to divide m data sample point into K clusters, so that each point belongs to the category corresponding to the cluster center (mean) closest to it, and use this as the clustering standard.

The dataset is represented by:

$$Y = (y_1, y_2, \cdots, y_m) \tag{1}$$

y_m in formula (1) refers to the m data sample point.

Each data sample in Y is a D-dimensional real vector. K-means clustering is to divide these m data samples into $K(K \leq m)$ sets, as follows:

$$A = \{A_1, A_2, \cdots, A_K\} \tag{2}$$

To minimize the sum of the squares of the clusters. That is, the goal of K-means is to find:

$$\arg_A \min \sum_{j=1}^{K} \sum_{y \in A_j} \left\| y - o_j \right\|^2 \tag{3}$$

o_j in formula (3) refers to the mean of the data in the j cluster A_j.

Assuming that the initial K mean points are known, the standard K-means algorithm alternates between the following two steps during learning:

(1) Assignment

Using Euclidean distance, the data point can be assigned to the observation point closest to it.

(2) Update

Calculate the new cluster center in each cluster obtained in step (1) as the new mean point.

This algorithm converges when each cluster center does not change. However, it should be noted that since there are only limited allocation schemes, this method will generally converge to a (local) optimal solution [10]. In semi-supervised or unsupervised learning, K-means clustering is often used for feature learning. The main purpose is to obtain a K-means cluster representation by training unlabeled data, and then map arbitrary input data to new feature space. After K-means clustering, the K-means clustering center can be used to extract features. The specific steps are as follows:

(1) Convolve the clustering results obtained above with the input data to obtain the characteristics of the input data.
(2) Generally, in order to reduce the number of feature dimensions, speed up the speed, reduce the network size and obtain a certain translation invariance, the feature maps obtained above are pooled.

Through the above steps, the output feature map of the k-means-based convolutional layer (unsupervised learning stage) is obtained.

Combined with the hardware modules designed above, the design of the IoT data acquisition system based on neural network combined with STM32 microcontroller is realized.

3 System Test

3.1 Indoor Environment Data Collection

The performance of the designed IoT data acquisition system based on neural network combined with STM32 microcontroller is tested. Use the system to collect indoor environmental data. The indicators collected mainly include three aspects: safety indicators, comfort indicators, and health indicators. Among them, the safety indicators focus on remote video monitoring of the indoor environment to know the status of the home. The comfort index is to monitor the indoor temperature, humidity and other indicators to make the indoor environment in a comfortable environment. Health indicators are to monitor indoor inhalable particles and some harmful gases. When the concentration of inhalable particles or harmful gases in the room exceeds the preset threshold, it can alarm in real time.

This part is mainly to test the data acquisition and data processing capabilities of the system. Due to the limitations of the laboratory sensor conditions, the test process takes the testing of temperature, humidity, smoke, carbon monoxide and carbon dioxide as examples to verify the data acquisition capabilities of the system and the data acquisition terminal. The function of wireless access to the IoT cloud platform. The test hardware consists of the following: voltage regulator source, data acquisition terminal, video camera, signal source, host computer, DS18B20 digital temperature sensor module, DHT11 digital temperature and humidity sensor module, MQ-2 smoke sensor module, MQ-7 carbon monoxide sensor module, MG-811 carbon dioxide sensor module composition. For the test of the data acquisition function, the signal source is used to simulate the high-speed signal, and it is connected to the data acquisition terminal.

In the IoT cloud platform, adding data acquisition terminals and sensor devices, the cloud platform can display the data of remote networked data acquisition terminals in real time.

The IoT cloud platform can view the data collected by the terminal in real time, and perform operations such as analysis and supervision. The collected data can be drawn into a curve, a pie chart or a bar chart. In the experiment, the front-end sensor constantly senses the external data, and the data collection terminal reports the data to the cloud platform every 5 s, corresponding to each node in the chart.

3.2 Data Acquisition Performance Test

The temperature, humidity, smoke, carbon monoxide, and carbon dioxide data collected in the experiment are shown in Table 4.

According to the test data in Table 4, the real-time collection of indoor environmental data can be achieved through the design system, which proves that the design system has good data collection performance.

3.3 System Communication Rate Test

Taking the Reference [2] system and the Reference [3] system as the experimental comparison method, the communication rates of different systems are tested, and the test results are shown in Fig. 2.

According to the test results in Fig. 2, the communication rate of the system in this paper is higher than 80 mbps, and it has been relatively stable at the same time. However, the communication rate of the Reference comparison system fluctuates greatly, and the communication rate is small. It can be seen that the communication rate of the system in this paper is large and the stability is strong.

Table 4. Data collected in the experiment

Serial number	Time (s)	Temperature (°C)	Humidity (% RH)	smoke(mg/m3)	Carbon monoxide(ppm)	Carbon dioxide(ppm)
1	500	25.30	36.25	34	10.10	200.36
2	1000	27.32	34.25	35	9.52	224.30
3	1500	26.85	36.20	28	8.63	212.62
4	2000	25.47	35.41	30	10.52	218.32
5	2500	26.41	36.20	30	11.63	204.36
6	3000	25.32	38.21	31	12.01	224.32
7	3500	24.10	36.32	32	9.32	201.32
8	4000	25.47	36.41	35	7.52	214.36
9	4500	25.63	36.20	36	9.30	214.32
10	5000	25.47	35.96	32	7.32	212.20
11	5500	26.52	36.14	30	8.52	231.0
12	6000	24.75	36.52	28	7.63	214.20

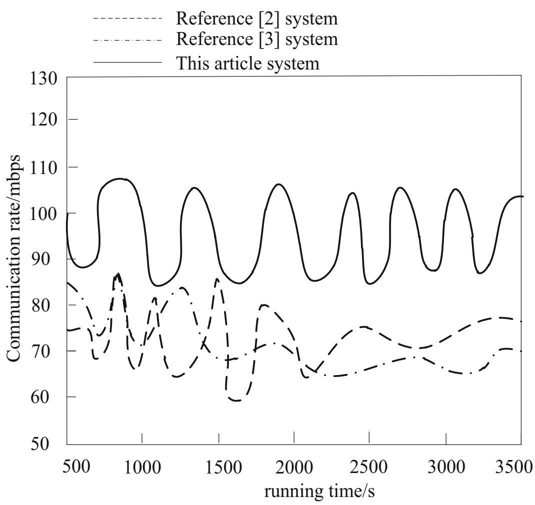

Fig. 2. Communication rate test results of the designed system

3.4 Power Consumption Test of Data Acquisition Terminal

The power consumption test results of the data acquisition terminal of the design system are shown in Table 5.

The test results in Table 5 show that, compared with the Reference comparison system, the power consumption of the data acquisition terminal of the system in this paper has always been low. It shows that the system has good energy-saving performance.

Table 5. Data acquisition terminal power consumption test results

Serial number	Acquisition time (s)	Power consumption/W		
		This article system	Reference [2] system	Reference [3] system
1	500	0.25	0.56	0.64
2	1000	0.48	0.78	0.82
3	1500	0.62	0.88	0.91
4	2000	0.85	1.20	1.15
5	2500	1.02	1.32	1.30
6	3000	1.26	1.48	1.51
7	3500	1.48	1.83	1.96
8	4000	1.68	2.01	2.09
9	4500	1.88	2.28	2.45

4 Conclusion

The data acquisition system of the Internet of Things is the layer closest to the perception of the surrounding environment in the Internet of Things layer. It is also the tentacle of the Internet of Things and the most important part of the Internet of Things. In the research, through the experimental verification, the designed data acquisition system of the Internet of Things can realize the real-time collection of indoor environmental data, the power consumption of the data acquisition terminal is low, and the system communication rate is stable.

However, the designed system still has some shortcomings. For example, the system can not realize the simultaneous collection of multiple Internet of Things at the same time. In the future, some expansion and improvement can be made on this basis.

References

1. Wang, Y., Gao, Y.: State prediction simulation of IoT terminal secure access data gateway. Comput. Simul. **39**(4), 341–344, 356 (2022)
2. Yan, G., Huang, X., Haiwu, X.: Design of a wireless sensing data acquisition system for NB-IoT. Modern Electron. Technol. **44**(18), 38–42 (2021)
3. Jia, J., He, Y., Hong, Y.: Design of multi-channel data acquisition system based on Internet of Things. Ind. Instrum. Autom. **4**, 21–24 (2020)
4. Wang, M., Liu, W., Xu, Y., et al.: Single-chip hybrid integrated silicon photonics transmitter based on passive alignment. Opt. Lett. **47**(7), 1709–1712 (2022)
5. Vinjamuri, U.R., Rao, B.L.: Efficient energy management system using Internet of things with FORDF technique for distribution system. IET Renew. Power Gener. **15**(3), 676–688 (2021)
6. Park, J., Kim, S., Youn, J., et al.: Low-complexity data collection scheme for UAV sink nodes in cellular IoT networks. IEEE Trans. Veh. Technol. (99), 1 (2021)

7. Sun, Z., Wei, Z., Yang, N., et al.: Two-tier communication for UAV-enabled massive IoT systems: performance analysis and joint design of trajectory and resource allocation. IEEE J. Sel. Areas Commun. (99), 1 (2020)
8. Sun, Z., Zhang, X., Wang, T., et al.: Edge computing in internet of things: a novel sensing-data reconstruction algorithm under intelligent-migratoin stragegy. IEEE Access, (99), 1 (2020)
9. Kim, T., Qiao, D.: Energy-efficient data collection for IoT networks via cooperative multi-hop UAV networks. IEEE Trans. Veh. Technol. **69**(11), 13796–13811 (2020)
10. Fazlollahtabar, H.: Internet of Things-based SCADA system for configuring/reconfiguring an autonomous assembly process. Robotica **40**(3), 672–689 (2022)