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*Research Article*

# Laboratory Intelligent Monitoring Operation and Maintenance Management System with Multisensor Technology

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Recently, following the rapid development of information technology and computer technology, various universities have higher and higher requirements for the management efficiency of their laboratories. Therefore, this paper studies the laboratory operation and maintenance management system (LOMMS) based on video surveillance, focusing on the detection and tracking of moving targets in the laboratory, and detecting possible abnormal behaviors. Compared with the traditional manual operation and maintenance management laboratory, the efficiency of LOMMS is significantly improved. At the same time, LOMSS video surveillance ensures the normal operation of the laboratory and the safety of the laboratory. This paper designs the complete scheme of LOMSS comprehensively with the video surveillance technology and the multisensor technology. First of all, through the detailed demand analysis of the university laboratory related staff, teachers, and students, the research objectives of LOMSS based on video surveillance are determined through repeated investigation with them. Secondly, through the demand analysis results, combined with the characteristics of LOMSS based on video surveillance, the system function is generally designed. Thirdly, based on the top-down principle, the overall function of the designed system is differentiated to obtain a more detailed functional map. At the same time, the database of LOMSS is designed to better store the data and other information in the system. The experimental results show that the temperature collected by the sensor is 10~30°C, and the humidity is 35~65%, which meets the environmental standards of the laboratory. This also shows that the test results of the sensor are normal, and also shows that the intelligent monitoring operation and maintenance management system (IMOMMS) of the laboratory meets the needs of the laboratory.

## 1. Introduction

With computer-related technologies and related facilities developed rapidly, university laboratories are also facing rapid adjustment. Traditional manual management loses the efficient characteristics of the laboratory monitoring, operation, and maintenance management system. Manual monitoring operations management laboratory system does not use advanced electronic equipment for efficient laboratory management, and when the laboratory abnormal behavior of the corresponding management system did not make abnormal judgment and corresponding response, which also makes the previous laboratory monitoring operations management system lose due value. An excellent and well-designed laboratory monitoring operation and maintenance management system will effectively improve the scientific research level of the whole university, so the role of designing an excellent laboratory monitoring operation and maintenance management system is self-evident. Although at present, the relevant laboratory operations management system is very diverse, but most of these software did not add relevant video monitoring function, which also makes the existing laboratory operations management system cannot adapt to the latest development trend, and the lack of video monitoring laboratory operations management system cannot maximize the safety of laboratory and students. At the present stage, many application systems are suitable for specific schools, and many universities are not comprehensive enough, which cannot bring convenience to the university management laboratory, nor can it fully meet the actual needs of the laboratory. Therefore, it is very necessary to design a LOMSS based on video monitoring.

In this paper, three different nuclear functions such as linear core, polynomial core, and Gaussian radial base core are used to train the monitoring operation and maintenance test experiment to determine the optimal nuclear function of laboratory monitoring operation and maintenance. Considering the results of three training tests, when the number of training samples is 180, the average correct identification rate of the monitoring operation and maintenance model is the highest, reaching 98. 61%. Therefore, this study uses the linear kernel function as the kernel function of the SVM. The temperature collected by the sensor is 10~30°C, and the humidity is 35~65%, which is in line with the environmental standard of the laboratory, which also shows that the detection result of the sensor is normal. It also shows that the laboratory intelligent monitoring operation and maintenance management system meets the needs of the laboratory.

## 2. Related Work

As a result, many scholars have provided a lot of reference. Hesti aimed to understand the extent to which operational activities affect the water system in the Trinondo marsh irrigation area. Andrews and Fecarotti reported an approach for combining Petri networks and Bayesian networks to study the impact of design and maintenance functions on the performance of the O & M management system [1, 2]. Ismail improved the traditional approach adopted in the Development and Facilities Management Maintenance Management System (MMS) of MIT [3]. Thaduri et al. emphasized the potential challenges, consequences, threats, vulnerabilities, and risk management of railway infrastructure data security in the context of electronic maintenance [4]. Ismail concentrated on building an integrated computerised maintenance management system to improve information storage for the design and construction, diagnosis, and defect risk assessment of IBS buildings through the Integrated Building Information Model (BIM) [5]. Guo et al. has established a remote operation system that greatly improves the operation level of charging piles. Recording the inspection results of operation and maintenance personnel can provide effective basis for performance assessment [6]. Alseiari and Farrell investigate the technical barriers to the successful implementation of full productive maintenance in the Abu Dhabi power industry [7]. Song et al. proposed a large equipment industry operation and maintenance (OM) management technology suitable for the wind power industry [8]. Mohanty et al. highlight different state monitoring tools and maintenance techniques to improve the reliability of ash pools [9]. Matveev and Matveeva have developed an autonomous three-channel digital recorder. The recorder is designed to meet the requirements of particularly harsh climatic conditions, minimum energy consumption, and easy maintenance [10]. The data used in these studies cannot be collected in real time, so multisensor technology can be used to collect real-time data. Regarding the multisensor technology, an all-fibre level sensor using a tandem multimode-single-mode-multimode (MSM) fibre structure is proposed and demonstrated by Sun et al. [11]. Zhang et al. studied a weighted fusion scheme for target tracking in underwater wireless sensor networks [12]. Therefore, this paper combines multisensor technology and OMMS to design a sensor-based OMMS to meet the needs of the public.

## 3. Method

This research aims to realize the automation, remote, and intelligence of laboratory video surveillance system and equipment operation and maintenance management, use of Internet technology and multisensor technology, reduce the pressure of manual maintenance and management laboratory equipment and system, and improve the efficiency and level of maintenance and management [13, 14].

This paper aims to realize the automation and intelligent operation and maintenance management (IOMM) of the laboratory video surveillance system, develop operational and associated hardware devices through software design. To test the operation status of the laboratory system equipment such as the camera, video signal, coding video equipment, video optical terminal machine, network switch, system management platform server in the system, intelligent analysis, detection and fault diagnosis of video quality, can realize real-time status monitoring, video inspection, equipment fault alarm, billing and settlement, fault query, fault statistics, and other operation supervision functions. The contents studied in this paper include the requirement analysis, the system overall design, the system detailed design, the software programming and implementation, the system deployment, and the practical operation testing [15].

Based on the current situation, construction mode, and operation mechanism, and taking it into account the future construction problems to reduce the cost of the system, that need to build a system operation and maintenance platform and ensure the normal operation of the system, the platform can effectively manage and monitor the main equipment, system, and link.

The overall hardware structure of the system is shown in Figure 1.

According to the requirements of the system function analysis, the embedded front-end machine takes AVR Atmega128 as the core, detects the environmental data through the sensor, uploads it to the monitoring center, and saves the data to the flash, while the processed laboratory environment variable information is displayed on the LCD screen. If there is a warning, the corresponding LED indicator will be lit.

The hardware structure of the laboratory intelligent monitoring system is mainly divided into the following parts:

Embedded front-end machine control module mainly composed of AVR processor and its peripheral circuits (including memory connection circuit, LCD display circuit, serial port expansion circuit, and power supply circuit.).

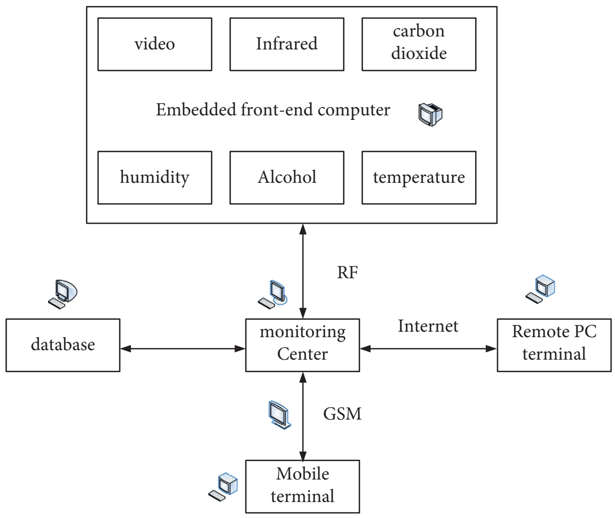


Figure 1: Overall topology.

Temperature sensor module: the temperature sensor DS18B20 of a single bus is directly connected to the port of the AVR.

Humidity sensor module: mainly put the wet sensitivity capacitor HS1101 in the TLC555 oscillation circuit.

Alcohol sensor module: the alcohol sensor and its peripheral test loop circuit.

CO 2 module: the connection of the CO 2 sensor TGS4161 to the ADC.

The laboratory intelligent monitoring system integrates temperature monitoring, humidity monitoring, carbon dioxide concentration monitoring, alcohol concentration monitoring, infrared alarm, and other multiple functions. The system designs temperature monitoring, humidity monitoring, carbon dioxide concentration monitoring, alcohol concentration monitoring, infrared alarm, and other modules.

This research collects data through multiple sensors in the hardware system, then integrates the data collected by multiple sensors through multisensor technology, and feeds back the processed data to the software system at the same time.

The system software part consists of device detection server, image detection server, management server, database server, Web server, client, and third-party service (mobile phone SMS, e-mail service) interface module, as shown in Figure 2.

The IOMM platform adopts a hierarchical, modular, and SOA service-oriented (the service-oriented architecture can deploy, combine, and use loosely coupled coarse-grained application components in a distributed manner through the network according to requirements) software architecture, which is divided into four levels:

Communication interface and service layer (as shown in Figure 3): through the unified interface adaptation service, it communicates with DVR equipment, bayonet equipment (future expansion), switch network management, optical terminal network management, video quality diagnosis system, obtain relevant status data, and write to the database.

Database layer (as shown in Figure 4): it uniformly stores relevant data information, including equipment information, engineering information, maintenance information, detection data, alarm data, department information, and personnel information; database design refers to the technology of database establishment and corresponding planning of each entity in the database, which is the core technology of laboratory monitoring, OMMS. Due to the relatively complex relationship between the entities in the database, in order to ensure the smooth procedures, great attention is needed to the database design, therefore. The arrangement and allocation of the entities in the database is a crucial step in the management and design of the laboratory monitoring, operation, and maintenance management system.

Application service layer (as shown in Figure 5): it provides basic services for the system maintenance management and application of the upper client, including equipment information management, data display, data query, alarm display, alarm distribution, server management, work order management, and WEB services.

Client layer (as shown in Figure 6) is the system management maintenance and application interface interface, responsible for the information interaction between users and the system. The client includes B/S end, C/S end, and mobile phone short message service.

The node information of the organization directory tree includes the number, name, parent node number, responsible person, telephone number, and other information. The data table design is shown in Table 1.

The video coding device information includes the IP address, communication port, name, number, number of video input ports, device type, brand, model, and video coding protocol. The database table design is shown in Table 2.

The video transmission channel information of the card slot is a subtable of the card slot information table, corresponding to the video transmission channel of a card slot of the optical terminal machine. The information includes serial number, video transmission channel number, and status. The data table design is shown in Table 3.

The information of network switch equipment includes number, name, network module IP address, and port number. The data table design is shown in Table 4.

Network switch: the network port information table is a subtable of the network switch information table, including the number, name, network management module IP address, and port number. The data table design is shown in Table 5.

Abnormal behavior detection mainly analyzes and identifies the motion target in the video scene, according to the movement-related information obtained by the motion target detection and tracking; it gives corresponding early warning to the identified abnormal behavior. Abnormal behavior detection is a key step of video surveillance technology, and detecting the abnormal behavior in the video also completes the core purpose of video surveillance technology.

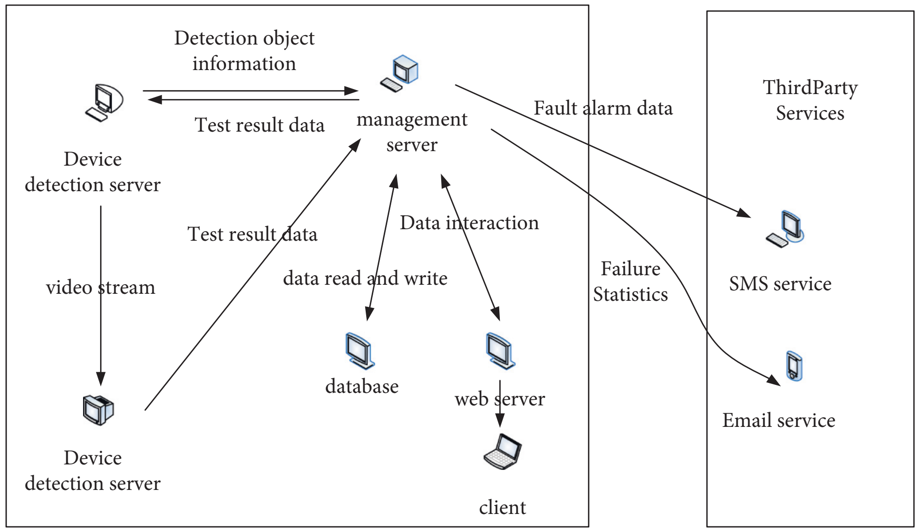


FIGURE 2: Schematic structure diagram of the intelligent OMMS.

This paper mainly realizes the detection of three abnormal behaviors, namely, target wandering, long time retention, and target transgression. The following three abnormal behaviors are analyzed in detail.

In the video surveillance system, if someone is found in the corridor outside the laboratory, there has been wandering action, which generally can not be regarded as normal behavior, easy to lead to criminal behavior. This is mainly because when a person has wandering behavior, he often reflects the inner anxiety and hesitation. It is generally closely related to crime which should be focused on monitoring, and general crime before need certain preparation. So, in this wandering, too long behavior is likely to be for time and conditions for crime. Therefore, in the video surveillance technology of this paper, a person will wander in the same place for too long as an abnormal behavior performance, and the system will identify and give early warning.

The video monitoring system determines the abnormal behavior of pedestrians wandering, which is generally based on the motion trajectory obtained by the motion target tracking. For the wandering abnormal behavior, because the wandering trajectory is mostly circular, it can be judged according to the movement trajectory. In conclusion, the test requires the following two steps to extract the trajectory of the target in the video and determine whether the behavior is according to the extracted trajectory.

The movement trajectory was extracted: pedestrian wandering abnormal behavior detection start, first through a motion direction four tuple to define the trajectory, namely composed of four four direction, the four motion variables value range only 0 or 1, motion involves the direction is 1, otherwise 0. So up and bottom, left and right cannot appear at the same time, is mutually exclusive relationship.

Judgment wandering abnormal behavior: it uses the first step to determine the trajectory, to determine the direction of movement in the pedestrian trajectory. According to the change of the movement direction in the pedestrian movement trajectory, the analysis starts from the pedestrian entering the video surveillance area, and the number of times opposite to the movement direction is counted as Num. If the Num is greater than the set threshold, the pedestrian wandering behavior is detected.

In the video surveillance system, monitoring target into the prohibited area will be regarded as the target cross abnormal behavior, mainly because in the video surveillance system, an unauthorized person appearing in key areas (such as laboratory key equipment reserves and laboratory key data storage area.) is likely to cause serious damage to the laboratory. Therefore, in general, if an unauthorized person appears in a key area and exceeds the specified time, the video surveillance system will use it as an abnormal behavior and make an early warning mark. Video surveillance system usually identifies the pedestrian abnormal behavior by tracking the motion trajectory obtained from the motion target.

The key to cross-border detection is to detect whether the target appears in the no-stop alert area. When the target enters the prohibited zone, it is considered as abnormal boundary behavior, and the target activity outside the prohibited zone is considered normal.

In a video surveillance system, if a person stays outside a lab for a long time, the system automatically treats the behavior as an abnormal behavior. It is mainly because in the video surveillance system. If a person stays in a place for too long, such as the door of the laboratory, reference room or key equipment room, he is likely to be doing improper unlocking or placing dangerous goods. Therefore, in general, in a place for a long time retention behavior, the video surveillance system will be regarded as abnormal behavior and early warning.

For long retention behavior detection, the video surveillance system is generally through the motion speed of this information to determine, namely for long stranded this behavior, the motion speed keep zero or almost zero state, the system will judge the behavior for a

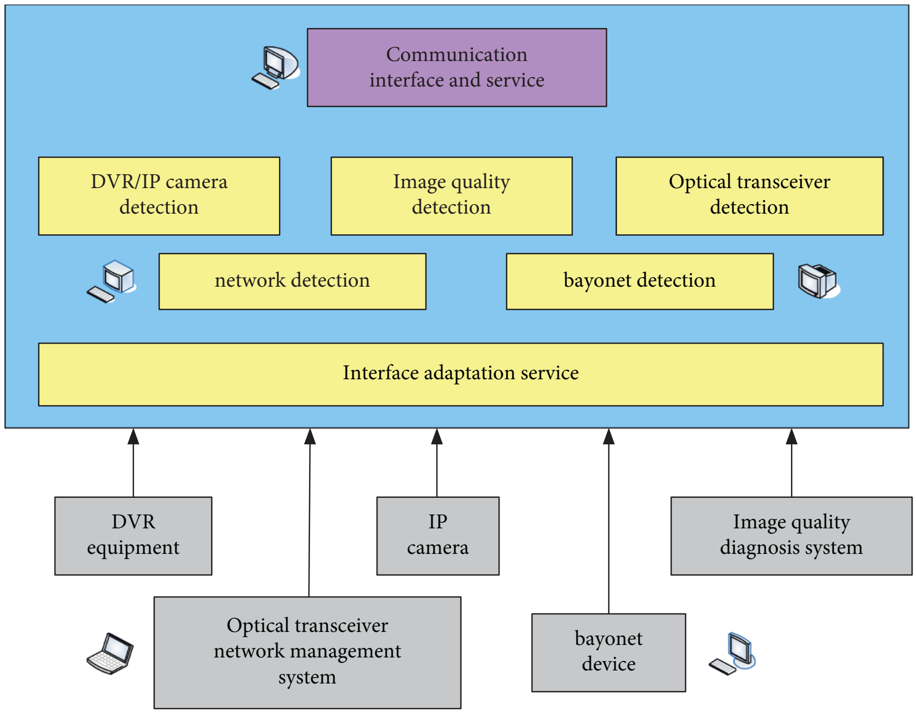


Figure 3: Communication interface and service layer.

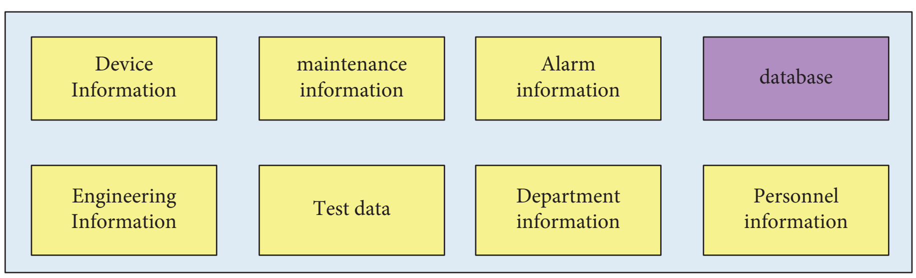


Figure 4: Database.

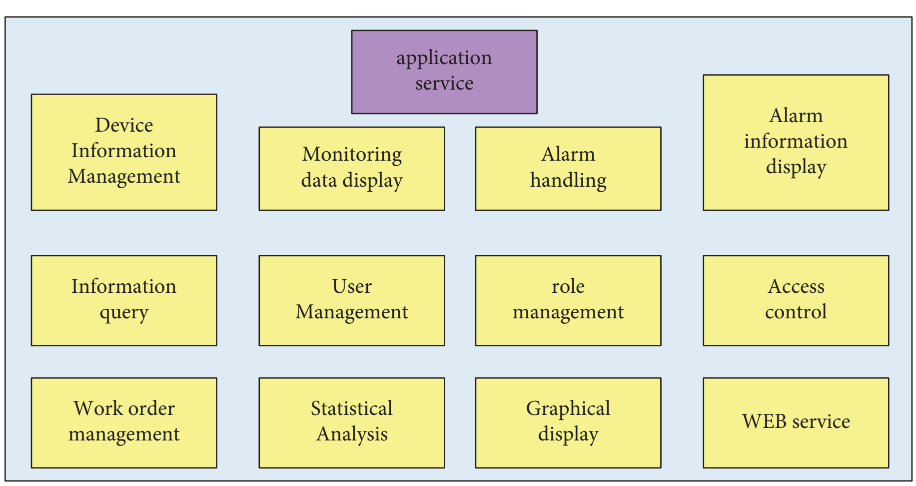


Figure 5: Application service layer.

long time, so as to complete the long stranded abnormal behavior detection. Target long-time retention behavior detection is mainly achieved through motion and time thresholds. When the movement speed of the moving target is zero or close to zero, the timing starts. When the timing time is greater than the time threshold set by the

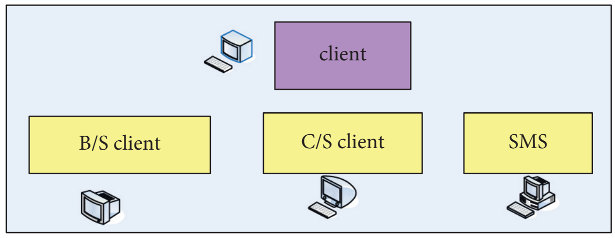


Figure 6: Client.

Table 1: The directory tree node information table.

| Field name | byte | Defaults | Illustration |
|---|---|---|---|
| ID | 20 | Automatic generated | Catalog number |
| Name | 20 | 0 | Directory name |
| ParentID | 25 | 0 | Parent node number |
| Leader | 12 | 0 | Principal |
| Phone | 32 | 0 | Phone number |

Table 2: Information table of the video encoding equipment.

| Field name | byte | Defaults | Illustration |
|---|---|---|---|
| ID | 20 | Automatic generated | Device ID |
| Name | 20 | 0 | Device name |
| ParentID | 25 | 0 | Parent node number |
| IPaddr | 25 | 0 | Network IP address |
| Port | 6 | 0 | Network port number |
| ChannelNum | — | 0 | Number of video input ports |
| DeviceType | 2 | 0 | Device type: 01-DVR/02-DVS/03-IP Camera |
| Model | 20 | 0 | Device model |
| CodeProtec | 20 | 0 | Encoding protocol |

Table 3: Video optical terminal machine information table.

| Field name | byte | Defaults | Illustration |
|---|---|---|---|
| ID | 20 | Reference video image information table IDtblid | Video image number, consistent with the video image information table ID |
| ChannelNO | 2 | 0 | The video transmission channel number corresponding to the card slot |
| Status | 1 | 0 | Channel status: 1-with video/0-without video |

system, the video monitoring system will judge the above behavior as the abnormal behavior of the target for a long time.

In the process of video surveillance, the camera is first used to collect the image sequence of the laboratory surveillance area and conduct the motion target detection and track of the collected video image sequence, so as to obtain the motion related information of the visual target, providing a large amount of information and clues for the subsequent abnormal behavior detection. Finally, based on the above information, the corresponding algorithm is designed to detect the abnormal behavior of the motion targets. If the abnormal behavior detection fails, no abnormal behavior occurs, indicating that the behavior in the video surveillance area is normal, and the video surveillance will continue. When the abnormal behavior is successfully detected, it indicates that the abnormal behavior has occurred, and the corresponding text annotation is made according to the detected abnormal behavior. At the same time, the corresponding early warning is given.

This paper uses the multisensor data fusion method of support vector machine (SVM).

Let the sample set $\{(\Omega_\Gamma, \Xi_\Gamma), \Gamma = 1, \ldots, \Lambda\}$ be a set of linear separable points, where $\Omega \in \Psi^\Sigma$ and $\Sigma$ are the dimensions of the sample space, and $\Xi \in \{+1, -1\}$ is the sample classification number, then the linear discriminant function and classification surface equation in the $\Sigma$ -dimensional space:

Table 4: Network Switch information table.

| Field name | byte | Defaults | Illustrate |
|---|---|---|---|
| ID | 20 | Automatic generated | Numbering |
| ParentID | 25 | 0 | The directory node number to which it belongs |
| Name | 20 | 0 | name |
| IPaddr | 25 | 0 | Network IP address |
| PortNum | 6 | 0 | Number of network ports |

Table 5: Network switch port information table.

| Field name | byte | Defaults | Illustrate |
|---|---|---|---|
| ID | 20 | Automatic generated | Port number |
| ChannelNO | VARCHAR(2) | 0 | Corresponding network optical transceiver port number |
| Status | 1 | 0 | Port status: 1-normal/0-abnormal |
| FlowRate | 20 | 0 | Network traffic |

$$\Pi(\Omega) = \Theta \cdot \Omega + \Phi, \quad \Theta \cdot \Omega + \Phi = 0. \tag{1}$$

When satisfying formula (2), find the minimum value of the function (3).

$$\Xi_\Gamma[(\Theta \cdot \Omega) + \Phi] - 1 \geq 0, \quad \Gamma = 1, 2, \ldots, \Lambda, \tag{2}$$

$$\Delta(\Theta) = \frac{1}{2}\|\Theta\|^2 = \frac{1}{2}(\Theta \cdot \Theta). \tag{3}$$

By solving the optimization problem, the optimal classification function is obtained as follows:

$$P(\Omega) = \mathrm{sgn}\left(\sum_{\Gamma=1}^{\Lambda} \zeta^{\&}\Xi_\Gamma(\Omega_\Gamma \cdot \Omega) + \Phi^{\&}\right), \tag{4}$$

where sign () is thesymbol function, $\Omega_\Gamma$ is the support vector, $\zeta^{\&}$ is the $\Omega_\Gamma$ corresponding Lagrange coefficient, $\Omega$ is the sample to be tested, and $\Phi^{\&}$ is the classification threshold.

In the case, the sample set is linear inseparable, then a relaxation factor $\forall_\Gamma \geq 0$ and penalty parameter $\tau$ are added, and then the minimum of the function (5) is obtained under the constraint of Equation (6).

$$\Xi_\Gamma[(\Theta \cdot \Omega) + \Phi] - 1 + \forall_\Gamma \geq 0, \quad \Gamma = 1, 2, \ldots, \Lambda. \tag{5}$$

$$\vee(\Theta, \forall) = \frac{1}{2}(\Theta \cdot \Theta) + \tau\left(\sum_{\Gamma=1}^{\Lambda} \forall_\Gamma\right). \tag{6}$$

Linear kernel function:

$$\ni(\Omega, \Xi) = \langle \Omega, \Xi \rangle. \tag{7}$$

Secondary kernel function:

$$\ni(\Omega, \Xi) = \langle \Omega, \Xi \rangle(\langle \Omega, \Xi \rangle + 1). \tag{8}$$

Term kernel function:

$$\ni(\Omega, \Xi) = (\langle \Omega, \Xi \rangle + \iota)^{\Sigma}, \tag{9}$$

where $\iota$ is the constant and $\Sigma$ is the polynomial exponent. When $\iota = 0$, $\Sigma = 1$, the kernel is a linear kernel.

Radial basis core function:

$$\ni(\Omega, \Xi) = \exp\left\{\frac{|\Omega - \Xi|^2}{2\partial^2}\right\}, \tag{10}$$

where $|\Omega - \Xi|$ is the distance between two vectors, the $\partial$ is constant.

Multilayer perceptron kernel function:

$$\ni(\Omega, \Xi) = \tanh(\nabla^* \langle \Omega \cdot \Xi \rangle - \#), \tag{11}$$

where the $\nabla, \#$ are the scale and decay parameters.

Several algorithms commonly used for motion object detection include frame difference method, background subtraction method, and background modeling.

Frame difference method:

$$\Diamond_@(\Omega, \Xi) = \left|\lambda_@(\Omega, \Xi) - \lambda_{@-1}(\Omega, \Xi)\right|, \quad \lambda_@(\Omega, \Xi) = \begin{cases} 1, & \Diamond_@(\Omega, \Xi) > @, \\ 0, & \Diamond_@(\Omega, \Xi) \leq @, \end{cases} \tag{12}$$

where @ is the threshold value, which $\Diamond_@(\Omega, \Xi)$ is the image after the difference.

Background subtraction:

$$\Diamond_@(\Omega, \Xi) = \left|\lambda_@(\Omega, \Xi) - \theta_@(\Omega, \Xi)\right|, \quad \lambda_@(\Omega, \Xi) = \begin{cases} 1, & \Diamond_@(\Omega, \Xi) > @, \\ 0, & \Diamond_@(\Omega, \Xi) \leq @. \end{cases} \tag{13}$$

Background Modeling:

$$\theta_@(\Omega, \Xi) \sim \Lambda(!, \%). \tag{14}$$

Among them, ! is the mean and% is the variance.

Background to initialize:

$$!(\Omega, \Xi) = \frac{1}{\Lambda}\sum_{\Gamma=0}^{\Lambda-1} \lambda_\Gamma(\Omega, \Xi), \quad \%(\Omega, \Xi) = \frac{1}{\Lambda}\sum_{\Gamma=0}^{\Lambda-1} \left[\lambda_\Gamma(\Omega, \Xi) - !(\Omega, \Xi)\right]^2. \tag{15}$$

Update the background image:

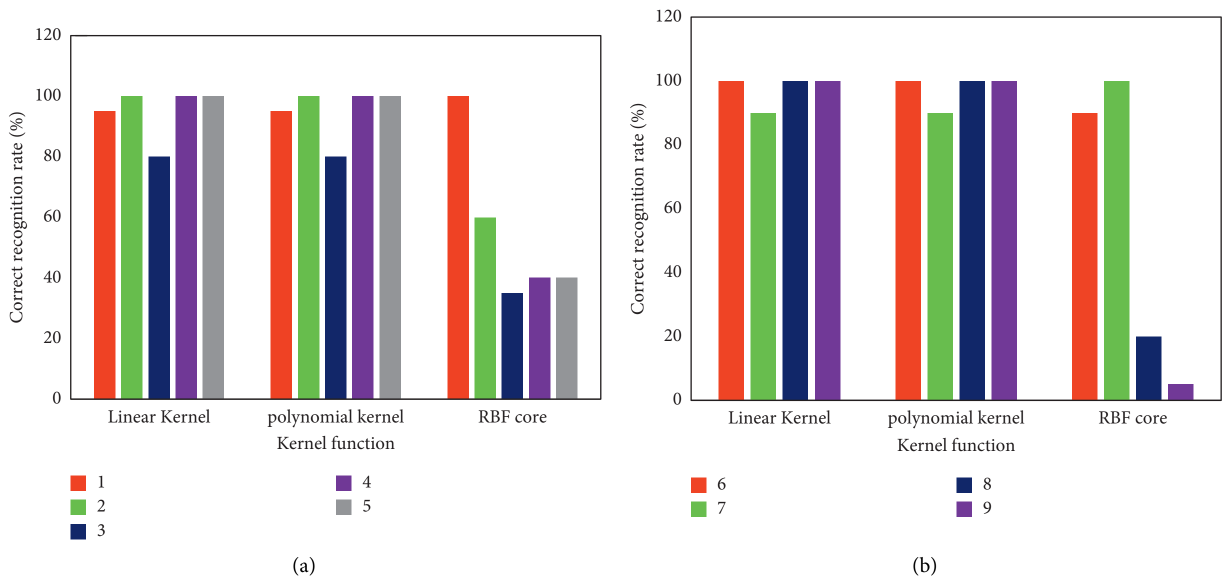


FIGURE 7: Test results of different kernel functions when using 72 training samples.

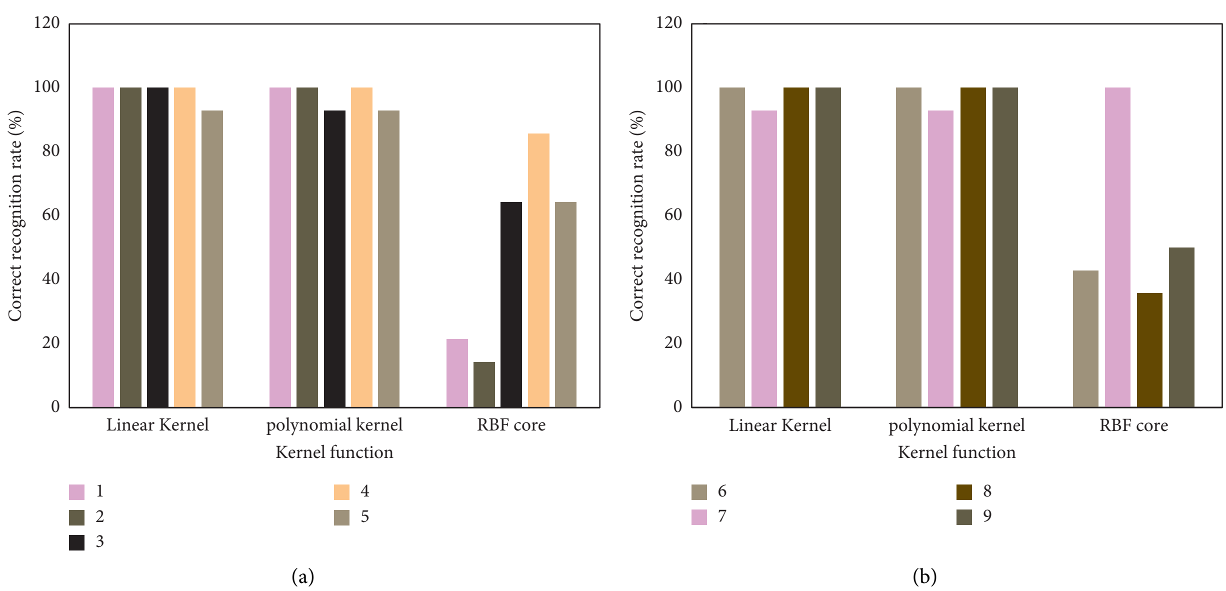


FIGURE 8: Test results of different kernel functions with 126 training samples.

$$\theta_\Gamma(\Omega, \Xi) = (1-\varepsilon)\theta_{\Gamma-1}(\Omega, \Xi) + \varepsilon\lambda_\Gamma(\Omega, \Xi). \quad (16)$$

where $\varepsilon$ is the background update parameter, which is a constant that reflects the background update rate.

## 4. System Experimental Simulation and Result Analysis

Monitoring data of 72,126 and 180 sets were taken as training samples, where each control class selected 8,14 and 20 sets, and the remaining samples of 180,120,72 sets were used as test samples. The SVM laboratory monitoring operation and maintenance model were constructed for testing, and the results are shown in Figures 7–9.

According to the experimental results in Figures 7–9, when the training samples are 72, linear kernel and polynomial kernel have the highest average correct recognition rate of 96. 11%. When the training sample number is 180, linear kernel is adopted, the average correct recognition rate of monitoring operation and maintenance model is 98. 61%; and RBF kernel function is adopted, the average correct recognition rate of monitoring operation and maintenance model is 65. 27%. The acquisition of the laboratory temperature sensor and the humidity sensor is shown in Figure 10.

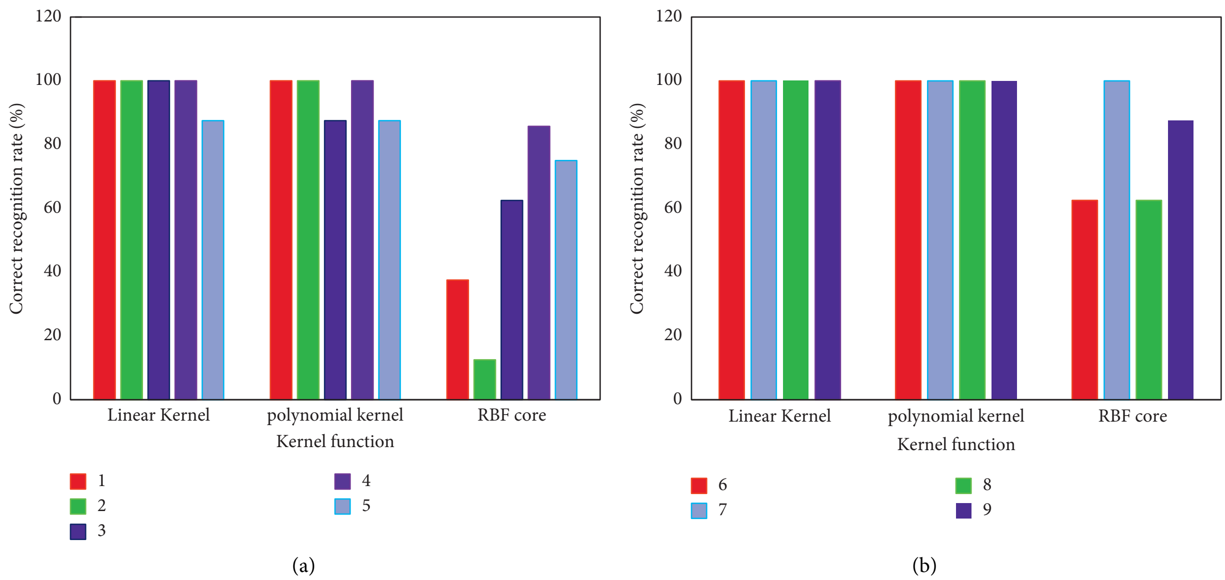


Figure 9: Test results of different kernel functions when using 180 training samples.

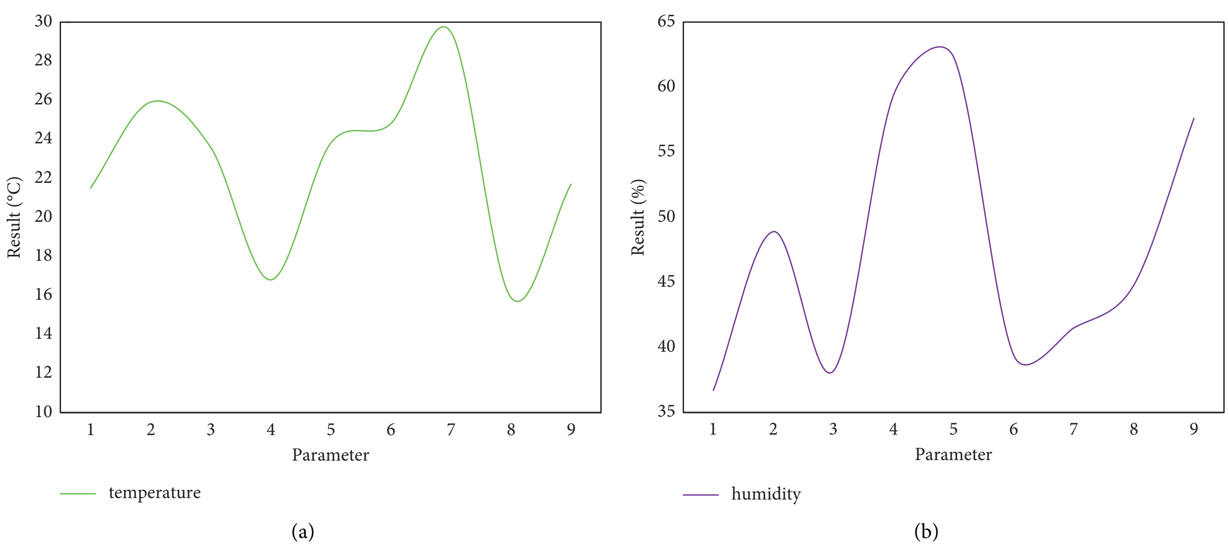


Figure 10: Acquisition of the laboratory temperature sensor and the humidity sensor.

Figure 10 shows that the temperature collected by the sensor is 10~30°C and the humidity is 35~65%, which meets the environmental standards of the laboratory. This also shows that the test results of the sensor are normal and indicates that the intelligent monitoring and operation management system of the laboratory meets the needs of the laboratory.

## 5. Conclusion

In order to manage the laboratory more conveniently, this paper designs a laboratory intelligent monitoring operation and maintenance management system through multisensor technology. The system includes two modules: hardware and software. The hardware system is composed of AVR Atmega128 chip, multiple sensors, and it is composed of monitoring and other equipment, and the data collected by the sensor are fused through the multisensor data fusion method of SVM to complete the collection and monitoring of laboratory data. The software part is to process the data, and also in order to provide an operation and maintenance platform for the operation and maintenance personnel, the data collected by the sensor are finally analyzed experimentally, and the conclusion shows that the laboratory intelligent monitoring OMMS meets the needs of the laboratory. Although the design and implementation of the system are smooth, the construction of the system is not accomplished overnight, the investigation work is relatively smooth, and the thinking is relatively clear, but the compatibility problem in the development process accounts for a considerable part of the energy and time to realize, which is in line with thefFeatures of system development that integrates resources.

## Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

## Conflicts of Interest

The authors declare no conflicts of interest.

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