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# Development and Research of Safety Video Monitoring System for Loading and Unloading of Chemical Products in Railway Transportation



**Abstract:** - As the important position of chemical railroad transportation in modern logistics is becoming more and more prominent, its safety problem has attracted wide attention. To improve the safety of transporting chemicals by rail, this paper strives to develop an advanced safety monitoring system. The main background of this paper is the serious potential results of chemical products railroad transportation accidents which require an effective monitoring method to prevent. The purpose of this research is to design and realize an efficient and reliable video monitoring system to monitor the loading and unloading of chemicals transported by railroads in real-time. To achieve this goal, we adopted comprehensive methods, including video image recognition technology, data analysis technology, communication network technology, etc., which have significant meaning in preventing railroad accidents of chemical product transportation and safeguarding people's life and property.

**Keywords:** Railroad transportation loading and unloading; Chemicals; Transportation safety; Real-time monitoring

## I. INTRODUCTION

### A. Research Background and Meaning

Because of the fast expansion of the global chemical industry, both demand and production of chemicals soars, boosting economic growth and logistic demand. The safety of chemicals during transportation has aroused public and governmental concern due to their flammable, explosive, corrosive, and toxic properties.[1] Traditional monitoring methods such as manual inspection and sensor monitoring have limitations. Therefore, it is particularly important to develop a system that can monitor the potential risks of railway chemical transportation and loading and unloading in a real-time and comprehensive way. Among them, video surveillance technology combined with modern image recognition and deep learning is gradually becoming a research hotspot to provide a higher level of security.

### B. Foreign Research Status

In foreign countries, the research on the safety of chemical loading and unloading in railway transportation focuses on the development of advanced video surveillance systems, using a number of technologies such as high-definition cameras, infrared technology, and sensors to achieve all-round monitoring of transport vehicles. Through image recognition, video analysis, and artificial intelligence, the system can automatically detect abnormal situations, such as leaks and fires, and take timely measures. At present, the development of information technology has reached a new stage, and the rapid development of artificial intelligence, big data, Internet + other technologies [2] can combine real-time monitoring with big data analysis, identify high-risk areas, and provide important information for decision-makers. Telecommunications technology and emergency response systems enable monitors to access information and respond at any time. The integration of regulations and standards helps ensure that the system meets safety requirements, improves the safety and reliability of chemical transportation, and provides a reference value for similar projects in other countries.

### C. Domestic Research Status

Domestic railway transportation is one of the main transportation modes for chemical products, [3] and its safety has attracted wide attention. Research on the safety of chemical products in railway transportation is committed to developing a sound video surveillance system, using high-performance camera technology, research intelligent analysis algorithms and sensors to build intelligent analysis and other technologies [4] to achieve real-time monitoring and control of the transportation process. Through image recognition, data analysis and other means, the system can quickly find abnormal situations such as leakage, fire, and timely alarm response. With the support of big data and cloud computing, domestic research is also focusing on the comprehensive utilization of

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transportation data to optimize transportation schemes and improve safety. At the same time, domestic research has also made efforts to formulate relevant regulations and standards, integrate the monitoring system into the transportation management system, and promote the improvement of the safety level of chemical transportation.

#### D. Purpose and Meaning of Research Content

The research of video monitoring systems for chemical safety in railway transportation aims to effectively prevent and deal with safety accidents that may occur in the process of chemical transportation, and ensure the safety of personnel and property as well as the health of the environment. Through the development of advanced monitoring technology, real-time monitoring of transport vehicle status, [5] timely detection and treatment of potential risks, reducing the possibility of accidents. The significance of this research is to improve the safety of chemicals transported by rail and reduce the risk of accidents, while also having an important impact on the construction of a more sustainable transport system and environmental objectives, further promoting the technological innovation and modernization of the rail transport industry.

### II. THE SAFETY PROCESS AND PROBLEM ANALYSIS DURING TRANSPORTATION, LOADING AND UNLOADING

#### A. Overview of Transport Handling Safety Operation Process

1) *Classification and labeling of chemicals*: Classifying the chemicals according to international and domestic standards, and clarifying their hazards. [6] Clearly identify the category, nature, storage, and transportation requirements of chemicals on the cover.

2) *Chemical packaging and container inspection*: Using special packages and containers that fit international and domestic standards. Inspecting the container for strength, tightness, etc., to make sure there is no risk of leak.

3) *Loading and fixing*: Select suitable locomotive carriages according to the characteristics of chemicals. Ensure even distribution of chemicals during loading and avoid excessive concentration. Using special tools and equipment to fix chemicals to avoid shifting and collision. At the same time, ensure that all loading and unloading technicians are licensed, which can improve their safety awareness and ensure the quality of loading and unloading. [7]

4) *Transportation*: Adjusting speed and path according to the route, weather, and other real-time conditions. During transportation, regular inspections are needed to make sure the safety of chemicals.

5) *Discrepancies in regulations and standards*: Chemical transportation standards and regulations vary with countries and regions, resulting in confusion and risk in transnational transportation.

#### B. Problem Analysis

##### 1. Human error

Leakage, damage, or other risks of chemicals may result from operator negligence or unfamiliarity with the process.

##### 2. Technical defects

Packages and fixed tools or other equipment may have quality problems or abrasions which may affect the safety of chemicals.

##### 3. Weather and nature factors

Extreme weather, earthquakes and other natural factors may lead to danger in transportation.

##### 4. Unsynchronized information

Unsynchronized information between the vehicle management system and field operators can lead to overstocking, loss, or other problems with chemicals. And this is labor intensive in terms of checking and confirming contents. [8]

##### 5. Discrepancies in regulations and standards

Chemical transportation standards and regulations vary with countries and regions, resulting in confusion and risk in transnational transportation.

### III. DESIGN AND IMPLEMENTATION OF SAFETY VIDEO MONITORING MANAGEMENT BACKGROUND (ANALYST MODULE) FOR TRANSPORTATION HANDLING

#### A. Design Feasibility Analysis

1) *Technical feasibility*: the system uses open-source, stable technology frameworks, such as Idea, Tomcat8.5, MySQL, etc., with mature technology, problems are easy to solve.

2) *Economic feasibility*: The program expenditure mainly focuses on equipment upgrades and server purchases, the technology used in the development process is open source and free of charge, and the economic burden is economically affordable.

3) *Operational feasibility*: the system is oriented to users with different roles, such as working foreman, analysis foreman, and administrator, and users who have a certain understanding of the system logic can operate the system, and it is recommended that training be conducted to improve the effectiveness of the system operation.

**B. Requirement Analysis**

1) *Functional Requirements*: The main functions of the system include adding system users, user login, viewing tasks, work assignment, task management, and operator management.

2) *User permissions*: different users have different permissions, for example, the operator can only log in to the APP, the working foreman can manage the operator and the workstation, and the video analyst can view and grade the work video.

3) *Performance requirements*: The system requires good interactivity, rigorous database design, high reliability, and security. The front end uses the EasyUI framework, the back end uses SpringMVC to handle exceptions, the database design abides by the three paradigms, and the security framework uses Shiro.

4) *Development environment and configuration*: The system belongs to a JavaWeb website system because it needs to be used with the camera flashlight, so it needs a client and server side. According to the development needs, JDK environment and mysql service are essential.

(1) Server side

Software environment: centos6.5 64-bit professional version or above, tomcat8.5+jdk1.8+mysql5.6

Hardware environment:

CPU: E5500 processor or higher

Memory: minimum 8GB, recommended 16GB

Hard disk space: minimum 20TB

Monitor: Support 1024×768 or above

(2) Client side

Software environment: Windows 7 32-bit professional version or above, 360 browser, Google Chrome 53 or IE11 or above, Adobe flash player 10.1 or above;

Hardware environment:

CPU: Intel Pentium 4 frequency  $\geq 3.2\text{GHz}$  Memory:  $\geq 2\text{GB}$  RAM

Hard disk:  $\geq 80\text{G}$

Graphics card: high-performance professional image processing discrete graphics card 2G

Sound card: DirectX 9.0c fully compatible

Monitor: 17-inch LCD monitor resolution to meet the 1024 \* 1024

**C. Hierarchical Block Diagram**

This system can be divided into the following hierarchy. [9] (Figure 1)

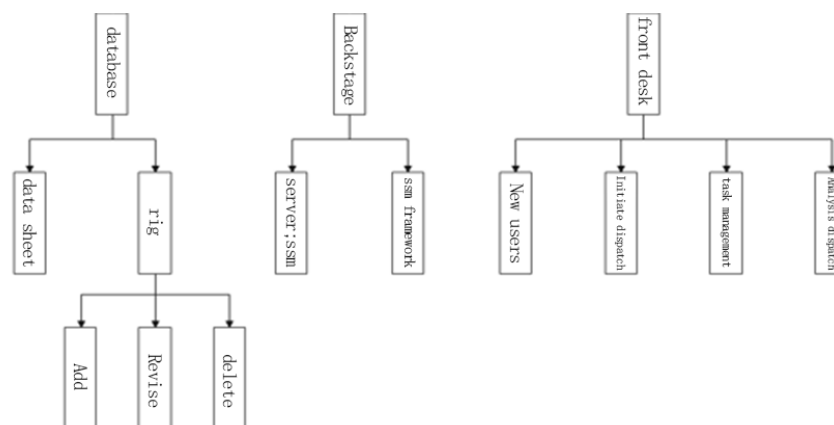


Figure 1 Hierarchical Block Diagram

*D. Use Case Diagram*

The example figure of this system is as follows:

1. The use case diagram of the whole system is shown in Figure 2



Figure 2 The Use Case Diagram of the Whole System

2. The use case diagram of the work assignment is shown in Figure 3

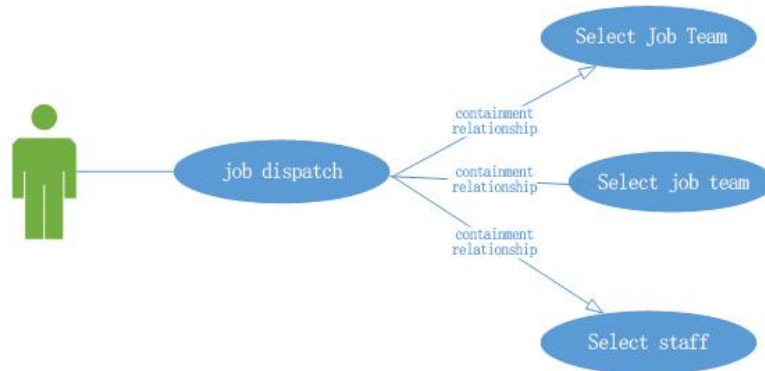


Figure 3 Use Case Diagram of Work Assignment

3. The use case diagram of video analysis is shown in Figure4

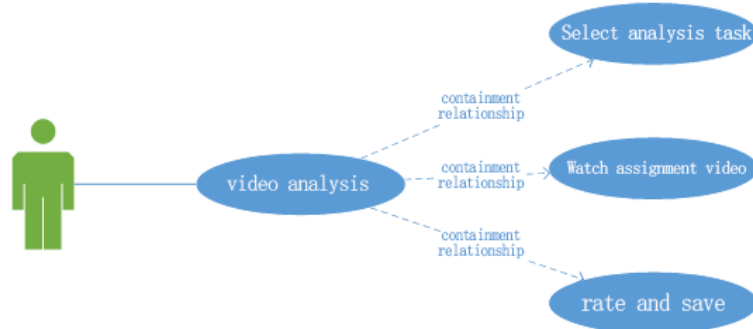


Figure 4 Use Case Diagram of Video Analysis

4. The security video surveillance system configuration diagram is shown in Figure 5.

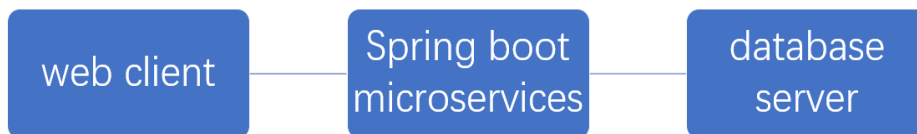
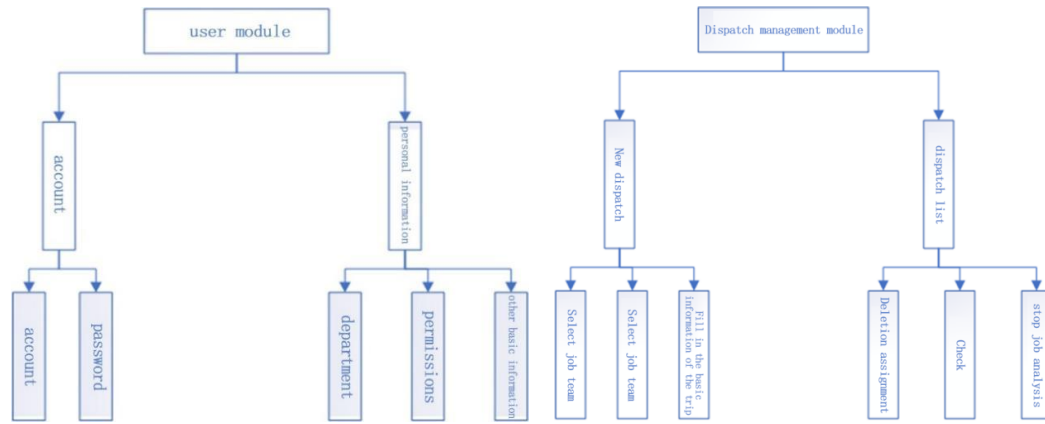


Figure 5 Security Video Surveillance System Configuration Diagram

*E. System Outline Design*

1. Hierarchical diagram of software modules: the hierarchical diagram of the user module is shown in Figure 6-a, 6-b.



(a) User Module Hierarchy Diagram (b) Hierarchical diagram of user modules

Figure 6 Diagram

2. The hierarchical diagram of the dispatch module is shown in Figure 7.

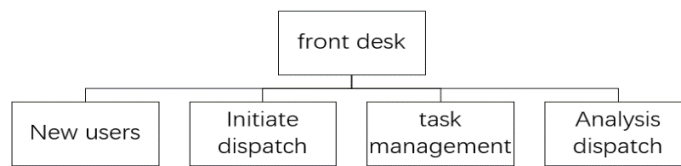


Figure 7 Hierarchical Diagram of the Dispatch Module

3. Logical structure design[10]

(1) Workstation table: every user whose role is aoperator can be added to anoperator, and only users who are called operators can be associated with a workstation. As shown in Table1.

Table 1 Workstation Table

field name	type of data	Is it empty	main key	description
Id	bigint	no	Yes	Worker Id
code	varcar	no	No	Work station number
name	varchar	no	No	Worker status
pid	int	Yes	No	Parent workstation Id
storage_id	bigint	Yes	No	Associated Video Classification

(2) Work assignment table: work statuses are (0: not assigned 1: work to be done 2: in operation 3: completed)

The status is 0 when the work is published, 1 when the work is assigned, 2 when the work is received by the operator, and 3 when the operator determines that the work is complete. The dispatch\_time field records when this task is released. The dispatcher\_id field records which user assigned the task. The work\_time field records the time it took for this task to be picked up from the operator until it was submitted. The group\_id field indicates the work group to which the work is assigned. Only the workers in the work group can obtain the work. As shown in Table 2.

(3) Analysis of the task table: when the operator obtains the task and shoots the video of the work, after confirming the completion of the task, the camera flashlight will call the relevant interface to generate a record. analyse\_by records the primary key of the analyst, which analyst received the analysis task. operator\_group records which work group completes the work, operator\_id records which operator completes the work. pri Indicates the priority of the analysis task. A higher priority is highlighted in the front-end list. As shown in Table 3.

Table 2 Job Task Table

field name	data type	Null or not	primary key	explanation
id	bigint	no	yes	job task id
train_number	varchar	no	no	train number
car_no	varchar	no	no	Vehicle group number
carriage_no_begin	int	no	no	Initial train number
carriage_no_end	int	no	no	end train no.
station_track	varchar	no	no	Railway branch line;
work_group	bigint	no	no	work team
repair_type	varchar	no	no	job type
status	tinyint	no	no	job status

dispatch_time	datetime	no	no	Allocate work time
work_time	datetime	no	no	job time
dispatcher_id	bigint	no	no	assignee primary key id
group_id	int	no	no	Job Team
shift	tinyint	no	no	Work shift

Table 3 Task Analysis Table

field name	data type	Null or not	primary key	explanation
id	bigint	NO	YES	Analysis task id
task_key	varchar	NO	NO	task code
task_name	varchar	NO	NO	task name
task_type	int	NO	NO	task classification
analyse_by	bigint	NO	NO	Analyst Primary Key
status	int	NO	NO	task status
alloc_time	datetime	NO	NO	Allocate time
complete_time	datetime	NO	NO	Complete time
car_no	varchar	NO	NO	Railway branch line;
carriage_no	varchar	NO	NO	train number
operator_group	varchar	NO	NO	work team
grade	varchar	NO	NO	Whether to score
pri	int	NO	NO	priority
operator_id	bigint	NO	NO	worker id

F. Network Architecture of the Project

The network architecture of the project is shown in Figure 8.

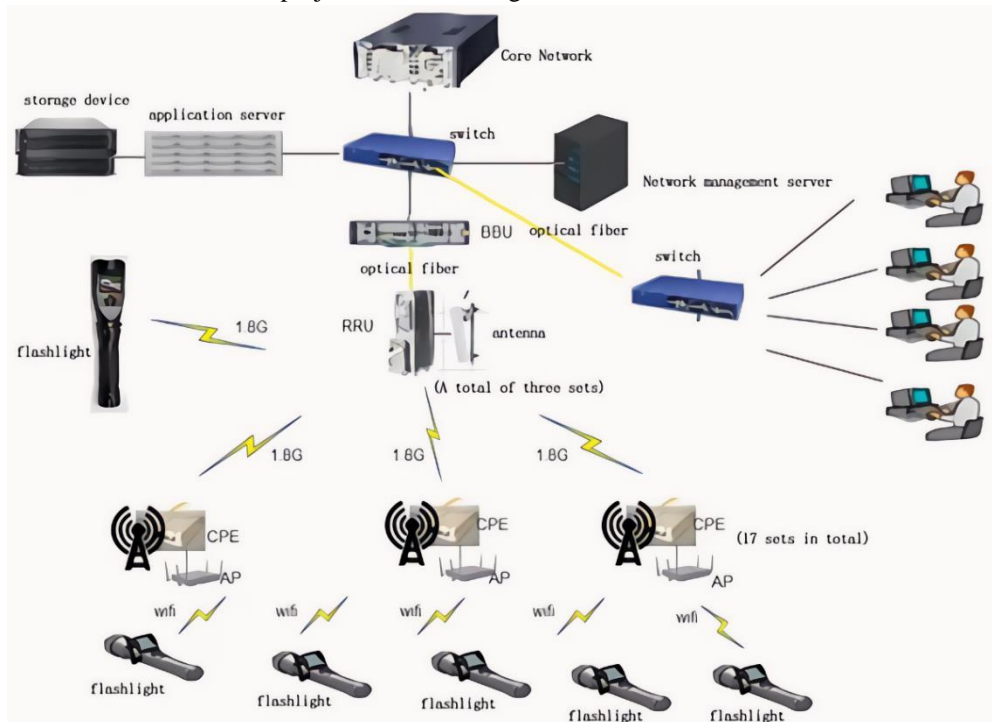


Figure 8 Network Architecture

G. System Interface Design and Module Implementation

1. Dispatch management module

① When the work factory logs in, you can see this interface, as shown in Figure 9. You can enter the car group number, select day shift/night shift, filter and query the work tasks during operation time, and click Clear to refresh the list and return to the initial state. The operation status is divided into waiting for dispatch, waiting for operation, working, completed. The bottom also adds a paging plug-in, you can directly enter the number of pages to jump to the corresponding number of pages, you can also directly jump to the last page or the first page, click the refresh button can also return to the first page.

Operation corresponding to the waiting for dispatch: dispatch and delete

Operation corresponding to the job to be performed: view and cancel, and return to the state of waiting for dispatch after cancellation

Operation corresponding to the completed work and work in operation: view, at this point the work holder has already received the task, so there can be no deletion. As shown in Figure 9.

Vehicle group number	Car No	work team	work team	Railway branch line	Loading and unloading type	job date	job status	Controls	
1	Vehicle group number 2	1--8	loading and unloading team A	team I	Railway branch line	Loading and unloading type	2021-05-17(day shift)	Waiting for dispatch	Dispatch <del>delete</del>
2	Vehicle group number 1	1--8	loading and unloading team A	team IV	Railway branch line	Loading and unloading type	2021-05-17(day shift)	Waiting for dispatch	Dispatch <del>delete</del>
3	Vehicle group number	1--8	loading and unloading team A	team I	Railway branch line	Loading and unloading type	2021-05-12(day shift)	working	check

Figure 9 Work Assignment Interface

② Click Add homework and you can see the interface as in Figure 10. The input data will be passed to the backend via json format. The special fields are work group and work team, work team indicates to which team the job is assigned, only the operator under the team can get the job, and the operator must be from the selected work group. The other fields are validated for non-null, and when the input is null, it will prompt "this input is required". As shown in Figure 10.

**Add homework** ✖

work group	loading and unloading team A	work team	[dropdown]
Vehicle group number	[red border]	Car No.	1 - 8
Train No.	[input]	type	[input]
Railway branch line	[input]	job time	2021-05-17 11:02:04

✔ sure
✖ close

Figure 10 Work Assignment Interface

③ Click View the Operation, and you can see the basic information of the task. The work team is more important. When the task is to be assigned, the basic information can be re-edited and confirmed. Except for the state "task to be assigned", the other states can only be viewed and cannot be changed.

2. Operator management

① This screen can be viewed when the job factory is logged in. As shown in Figure 11, this screen allows you to manage all operators. Note that the user is the user, the worker is the worker, and the user's role is the operator, but not necessarily the "operator", and needs to be added by the work foreman to become a real "operator". The business logic is that the information of the worker exists in the worker table, and only the users whose role field in the user table is jobber can be added to the worker table. In the tree diagram on the left, you can select the workers under a particular organization. For example, if you click on the workstation "Team 1", it will only show the worker associated with the workstation that has a team of workers. If you click on "Level 1", you will see the operators from "Team 1" to "Team 12". As shown in Figure 11.

② Click Add, as shown in Figure 12. Worker number is a required field, which represents the selection of which user to add to the worker table. The work team and job station are very important, only by correctly selecting the work team and job station, can you receive the relevant tasks in the camera flashlight. However, you can leave them unselected for now at this point. Confirmation or not means that the operator who is logged in to the app can be sure that the job is completed. On-duty status indicates whether the operator can log in to the app. Click on "Select operator". As shown in Figure 12.

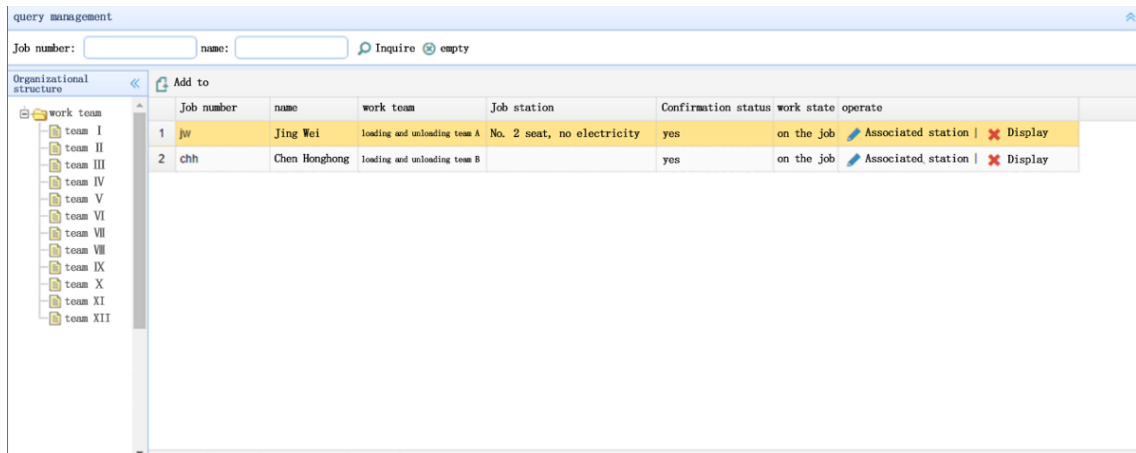


Figure 11 Worker Management

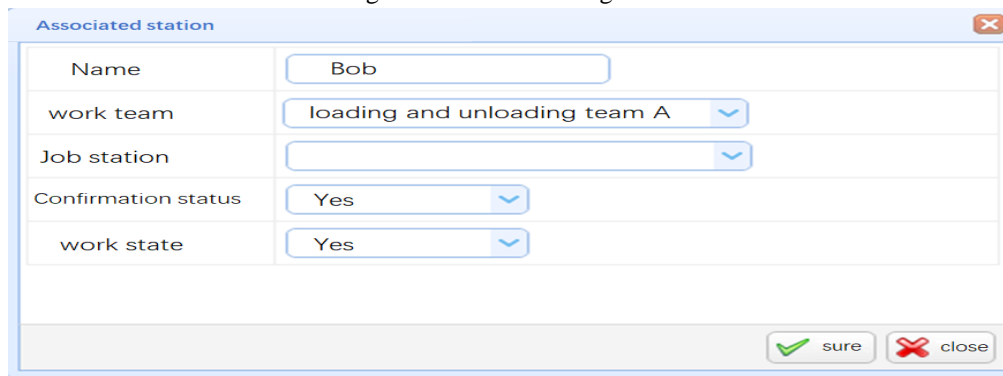


Figure 12 Adding New Operators

### 3. System management module

It is mainly for the system administrator to manage all the user information under the system, including their departments, and the corresponding roles, and each role corresponds to the permissions. Users can modify their account passwords and add new users.

#### (1) User management

① Click Add, as shown in Figure 13. Input boxes shown in red are non-empty validation, if the requirements are not met, it will be prompted that the input is mandatory. Login name and password are the user's credentials to log in to the system. Department, gender and age are irrelevant and will not affect the normal business logic. The selection of role represents the authority of this user, for example, if you select the work foreman, this user can manage the worker and also dispatch the job, so this field can't be selected indiscriminately but according to the actual situation. As shown in Figure 13.

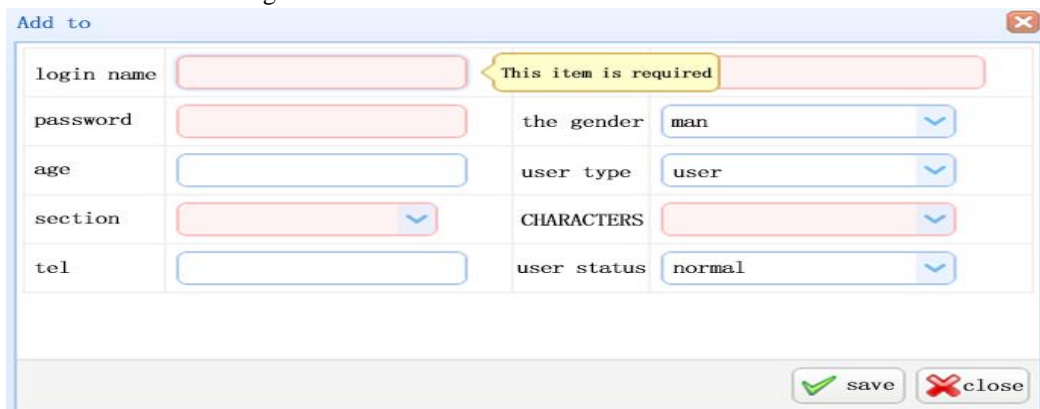


Figure 13 Adding a New User

#### (2) Role management

① Show all the roles of the system, and you can authorize the roles, as shown in Figure 14. under this interface, you can add new roles and give them the corresponding permissions, but generally at the beginning of the design of the system has been written in full, and rarely new roles will be added. As shown in Figure 14.



+ Add to						
ID ^	appellation	sequence	describe	state	operate	
1	administrator	1	super administrator	normal	Auth   Edit   Del	
2	ground operations	2	Foreman of ground operations	normal	Auth   Edit   Del	
3	Analytical foreman	3	Analytical foreman	normal	Auth   Edit   Del	
4	censor	4	censor	normal	Auth   Edit   Del	
5	worker	5	worker	normal	Auth   Edit   Del	
6	uploader	6	uploader	normal	Auth   Edit   Del	
7	Video Analyst	7	Video Analyst	normal	Auth   Edit   Del	

Figure 14 Role Management

② Click "Authorization", and you can see the existing permissions of a role, for example, the permissions of the work foreman, as shown in Figure 15, whose role can only perform operations under the assignment module, such as adding new assignments. As shown in Figure 15.

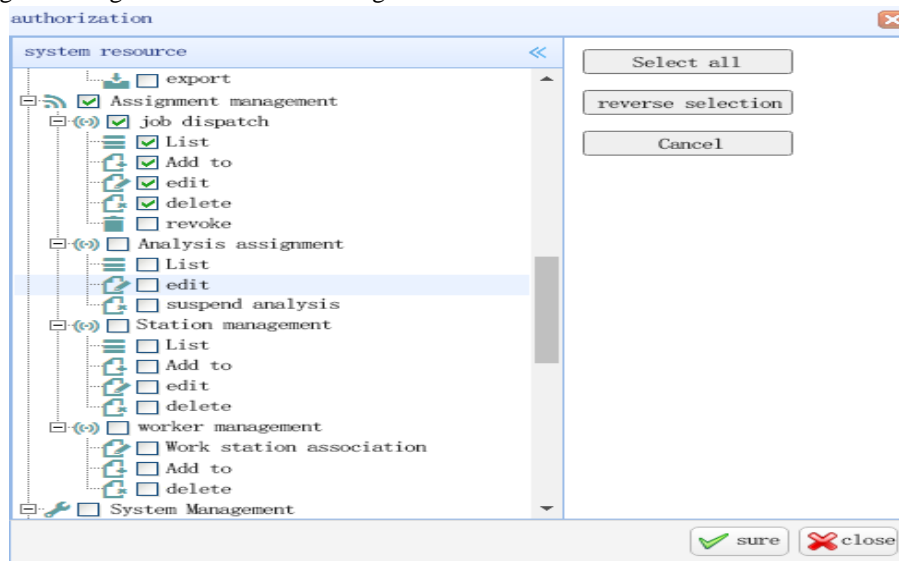


Figure 15 Role Authorization Interface

#### 4. Video analysis module

(1) The video analyzer can see this interface, all the pending tasks will be displayed here, as in Figure 16. whenever the operator completes a task in the user terminal, there will be one more record here. At the top of the table, you can search by task type, task code, and task name, and the table will list the records that match the query criteria. Clearing the query will clear all the query conditions and show all the records in the table.

Depending on the status of the task, the corresponding operations will be different.

Unassigned: The unassigned status means that the task has not been claimed, and the corresponding actions are "Edit" and "Rate".

Analyzing: The task has been claimed, but has not yet been completed. The corresponding actions are "Score" and "Details".

Analyzed: The task has been completed, but has not yet been reviewed. The corresponding actions are "Details" and "Review".

Reviewed: The to-do task has been completed. The only corresponding action is "Details".

Task Encoding	Task Name	Task Type	Task Status	creation time	operate
J8C-202305150245447374	Loading and unloading position one	Video Analysis	Analyzed	2023/5/15 2:45	details   review
J8C-202305150245447516	Loading and unloading position two	Video Analysis	Analyzed	2023/5/15 2:45	details   review
8G0JCY020231015204612	Loading and unloading position three	Video Analysis	Analyzing	2023/10/15 20:46	score   details
YHA202303140546SDFDF	rear	Video Analysis	Analyzing	2023/3/14 5:46	score   details
SDF1202205161646FGAS	Lifting gear	Video Analysis	Analyzed	2023/5/15 16:46	details   review
SDFQA202303151652AS	Reinforcement check	Video Analysis	Analyzed	2023/3/15 16:52	details   review
JSCASD202304150511AF	Vehicle inspection	Video Analysis	Reviewed	2023/4/15 5:11	details

Figure 16 To-do Tasks

(2)When you click "score", it will jump to the corresponding rating interface according to the video category of the to-do task. After entering the grading interface, the "Analyze Time" in the upper left corner will automatically start the timer. In this interface, you can watch the corresponding video under this task, and then fill in the grading form, after filling in the form, you can choose "Save" or "Submit, Save and Close". If you choose "Save", the scores will be retained for the next scoring. If you select "Submit, Save and Close", it means that the entire process of analyzing this task has been completed, and you cannot change the data you have entered. If you click "Close", the scores will not be saved. As shown in Figure 16.

IV. SYSTEM TESTING

A. Purpose of Testing

To test the functions realized by the "Video Monitoring System for Chemical Transportation and Handling Safety in Railway Vehicles", and to check whether it meets the customer's requirements.

B. Test Content

The test content mainly focuses on the user's use of the functional process, the transmission of the background database to test whether there are data error problems. The test content mainly includes the test of job dispatching, whether the operator can receive and transmit the video in the system, and whether the corresponding video list can be seen in the management backstage for the video transmitted in real-time. As shown in Table 4

Table 4 Test Content

No.	Content	Test method	Test result
1	Test for work assignment	(1) Using Chrome browser, open http://192.168.13.110/video and use admin admin to enter the system (2) Import the job schedule given by the day's scheduler. (3) Assign the generated task to the corresponding work team Requirements: (1) (2) (3) are working, and the assigned crews can be seen after the flashlight user logs in.	Be able to assign task for workers
2	Function test of flashlight APP	(1) The flashlight should have a 4G network and be able to log into the customized APP application (2) Be able to view the assigned tasks, and create and shoot a new and a specific homework video task (3) It can normally perform the status confirmation function when the assignment is completed. Requirements: (1) (2) (3) are normal	Workers could receive relevant tasks
3	Real-time uploading of work videos for testing	(1) The operator can see the job site in real-time in the background when using a flashlight for a specific task. Requirements: (1) normal	Operators are able to transmit real-time images of the job site.
4	Job video analysis test	(1) The operator can see the corresponding video list in the background after completing and uploading the shooting of a specific task using a flashlight (2) The operator can get the video analysis task by himself/herself, and the information corresponding to the video to be analyzed (operator, job content, locomotive number, job scoring template, etc. are normal), and score it. Requirements: (1) (2) (3) are all normal	For real-time video transmission, you can see the corresponding video list in the management background.

From the test results, this system can finish walking through a business process, indicating that there is no problem with the background of this system.

C. Test Conclusion

This solution addresses the real-time transmission of key loading and unloading transportation operation contents (e.g. video transmission and distribution) and builds an intelligent management system and network platform for overhaul workshop operations. A TD-LTE wireless broadband dedicated network is used, and camera tools are modified to provide mobile video monitoring by means of instantaneous ingestion and transmission. The system is capable of remote command and real-time monitoring, realizing real-time video browsing, retrieval, analysis and scoring, ensuring the safety of the whole process of locomotive overhaul.

## V. CONCLUSION

The safety of chemical transportation is important in railroad car transportation, this research and development of the monitoring system strengthens the safety control during transportation loading and unloading process, by using advanced computer vision and artificial intelligence technology, the system can accurately detect abnormal situations and immediately send out alarms to avoid accidents and provide a rapid response mechanism, which provides a new possibility to develop an efficient, flexible and reliable video monitoring system. This provides new possibilities for developing an efficient, flexible, and reliable video surveillance system.

While the system is theoretically efficient, in practice, a number of factors need to be taken into account, including the durability of the inspection equipment, the environmental conditions, and the performance of the system in the actual environment. We can continue to improve the system to provide more accurate monitoring results, increase response time, and reduce the potential for false alarms.

The development and research of the video surveillance system for chemical transportation and loading/unloading safety in railway vehicles not only helps to ensure the safe transportation of chemicals but also deepens our understanding of the application of video surveillance systems in special scenarios. Although some challenges were encountered during the research and development process, through continuous improvement and optimization, we believe that this system will have a broader application prospect in the future.

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