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RESEARCH ON THE STANDARDIZATION AND VISUALIZATION PLATFORM FOR MONITORING AND TESTING DATA OF METRO CIVIL FACILITIES BASED ON BIG DATA

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Abstract

Introduction: With consideration for extensive standardized detection and monitoring data, multi-source data fusion analysis and comparison were implemented at cross-project and inter-regional levels to provide robust data support for the full life-cycle management of metro civil facilities. The **purpose of the study** was to integrate detection and monitoring data on metro bridges and tunnel structures and address the significant data isolation issue in existing systems and various units. Based on big data and Internet of Things technology, this paper investigates the standardized format of uploading, storage, processing, sharing, and other types of managing detection and monitoring data on metro bridges and tunnel structures. Additionally, a third-party data standardization and visualization platform for bridges and tunnel structures was developed, ensuring integration of detection and monitoring data fusion. In the course of the study, the following **methods** were used: theoretical analysis and software system development. As a **result**, the practicability and feasibility of the platform were verified through practical applications.

Keywords: metro civil facilities, big data platform, detection and monitoring, data standardization, integrated analysis.

Introduction

With the rapid development of urban rail transit, the number of such civil facilities as bridges and tunnels increases. As the years of operation increase and the external environment constantly changes, the structure of civil facilities has undergone subtle changes, including shifts in existing diseases and the emergence of new ones. The monitoring and testing of bridges and tunnels have generated a large volume of paper records, charts, images, etc. (Fig. 1), encompassing various types of data from different sources, lacking unified data format standards, and leading to significant data fragmentation (Fig. 2). There is also a lack of an integrated management platform that would combine engineering structure overview, historical monitoring data, metro safety assessment, and structural maintenance history for the comprehensive application of civil engineering facilities. As a result, it is quite difficult to achieve the auxiliary management functions of visual querying, intelligent analysis, and comprehensive judgment of metro civil engineering structure operation and maintenance data.

The operation and maintenance management of urban rail transit civil engineering facilities has significant social benefits and broad application prospects. Many metro operators, manufacturers of information systems, and universities in China have started to dedicate more research and development efforts to the informationization of the operation and maintenance management of urban rail transit. For instance, Agrawal et al. (2011), Assunção et al. (2015), Beyer and Laney (2012), Chen and Zhang (2014), Mayer-Schönberger and Cukier (2013) introduced the definition, potential applications, and development trends of big data and cloud computing. Li (2020) proposed the fundamental concept of creating a cloud platform for managing urban rail transit detection data, focusing on system architecture and system function design. Tao et al. (2019, 2021) implemented a railway infrastructure testing and monitoring data management and integrated analysis service platform based on big data technology. Chen et al. (2012), Demirkan and Delen (2013), Ding and Guo (2015), Guo et al. (2016), Khribi et al. (2009), Lv et al. (2015), Peng et al. (2017) investigated the application of big data in various fields. Luo et al. (2019) and Yang (2021) analyzed the application and prospects of BIM technology in intelligent operation and maintenance in the railway infrastructure and urban rail transit industry. Vitri and Herman (2019) studied the basic infrastructure maintenance system for improving the quality of infrastructure services. Jamshidi et al. (2017) investigated the method of big data analysis for rail failure risk assessment. Wu et al. (2010) and Zach and Reiser (2015) studied the application of cloud storage.

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Fig. 1. Paper ledgers (charts)

Fig. 2. Standards for different data formats

However, most of the above-mentioned systems (GB 50911-2013 (Standardization Administration of the People's Republic of China, 2013), DB11/T 1167-2015 (Beijing Bureau of Quality and Technical Supervision, 2015), DB11/T 718-2016 (Beijing Bureau of Quality and Technical Supervision, 2016), GB/T 39559.2-2020 (Standardization Administration of the People's Republic of China, 2020)) only implement the related data collection and display functions and have shortcomings in data standardization, intelligent collection, and data fusion. These systems are unable to perform deep data analysis and safety control value deduction from the vast amount of operation and maintenance data, including monitoring, detection, and evaluation data.

Research on combined detection technology

In terms of data analysis and utilization, the data formats across different monitoring and testing units are quite diverse and independent of each other. As a result, the standardized data uploading interface, analysis algorithm, data visualization, and fusion analysis result display functions need to be redeveloped. Besides, data uploading standards vary for different sources, and the absence of batch processing functions for unstructured data leads to low data utilization.

This paper aims to achieve the fusion of monitoring and testing data for metro bridges and tunnel structures, addressing the significant data isolation issue between existing systems and various units. It will collect data sources and types, develop third-party monitoring and testing data uploading standards, and establish third-party data standardization and visualization to achieve modularization, standardization, platformization, and visualization. The platform includes a data layer, a service layer, and an application layer. The technical architecture of the platform is shown in Fig. 3, and the platform's functional modules are shown in Fig. 4.

The data layer connects data from various sources, with the fundamental information coming from the infrastructure ledger of the management unit. The test data comprises special test data from the third-party testing unit, with the primary data sources being the test reports and original records from previous years. The monitoring data includes all manual monitoring data from third-party monitoring units, with the primary data sources being the monitoring reports and original records from previous years. Data from various sources is classified and stored to achieve the integration of multi-channel data information. The data layer manages the storage of structured data, unstructured image data, report files, as well as monitoring, detection, and safety assessment. It also imports basic account information for civil engineering facilities such as bridges and tunnels, providing a data information basis for data fusion analysis. The service layer offers such services as data standardization processing, batch import, fusion analysis, and data visualization for each application layer. This fully supports the statistical analysis of monitoring and testing data for metro civil engineering facilities, disease type information description, state evaluation, treatment suggestions, and more.

Key technology

The system platform utilizes stable and advanced information technology for data classification storage, big data component integration, data utilization and deployment, efficient retrieval, and platform interface optimization. Additionally, it establishes a third-party monitoring and testing data platform for civil engineering facilities and reserves interfaces for future system upgrades.

The system platform utilizes big data technology based on the Hadoop ecosystem to achieve efficient storage and processing of massive data. This includes data cleaning, deduplication, aggregation, and correlation analysis processes. Through the MapReduce model for parallel computing, it is possible to accelerate the processing of large-scale datasets, quickly extract useful information and patterns, and achieve intelligent analysis and processing of stored data, to provide more

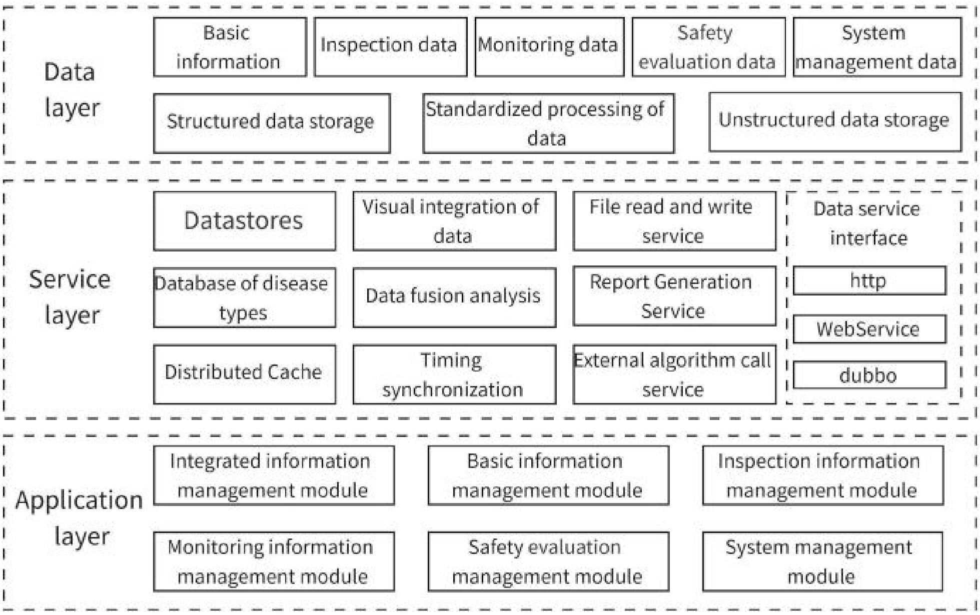


Fig. 3. Platform technology architecture

comprehensive and accurate support for the technical evaluation and subsequent management decisions regarding bridges and tunnels.

1. Data Classification Storage Technology

The platform comprehensively processes basic information data on bridges, health monitoring data, test management data, etc. The data organization forms vary in different scenarios. To meet the processing requirements of this type of multi-source heterogeneous data, the platform comprehensively utilizes multiple storage technologies to ensure efficient and secure data storage.

Data such as basic bridge information and test management information can be considered

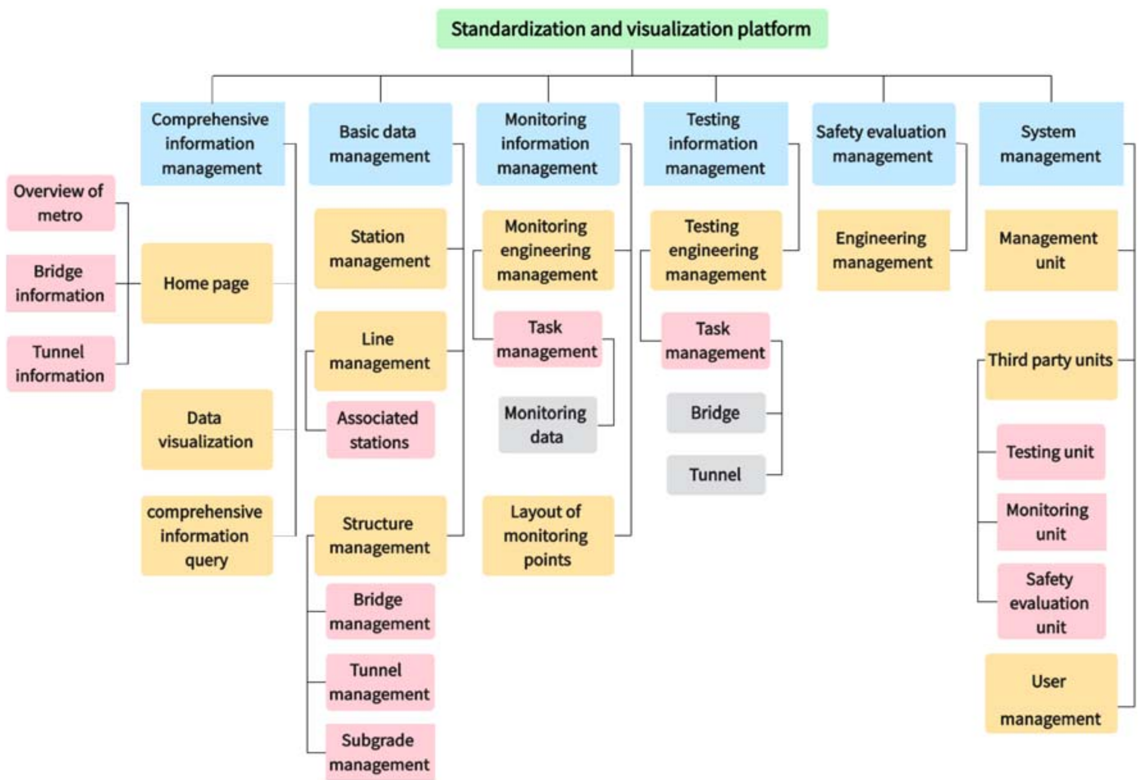


Fig. 4. Platform's functional modules

structured data, with high integrity and consistency, and a strict correlation between the data. The system uses the MySQL structured database to process this part of the business data and utilizes the SQL language for querying and managing the data.

Bridge health monitoring data can be considered time series data, which is arranged in a time sequence and has the characteristics of a large amount of data, more writing and less reading, and more statistical indicators. The system uses the TDengine time series database to store and query monitoring data, thereby improving monitoring data processing capabilities and reducing disk space occupancy.

Such information as test reports and images of diseases generally exists in the form of pictures and files. A single file has a small size, but there are many files. Therefore, the system uses the FastDFS distributed file system to store attachment files, which can effectively expand the storage capacity and meet the later operation and maintenance requirements.

2. Integration Technology for Big Data Components

The system uses the Spring Cloud framework to effectively integrate the big data-related components used in the platform development process, thereby achieving high service availability and improving the stability and scalability of the platform. A microservice is a software architecture style that divides applications into smaller components known as services, each of which runs, expands independently, and interacts through a lightweight communication mechanism. Based on the business requirements, the system divides the functional level and designs several microservices, including basic information management service, monitoring information management service, detection information management service, safety assessment management service, and comprehensive information management service.

Spring Cloud is an open-source microservice framework that provides out-of-the-box components such as service discovery, configuration management, intelligent routing, control bus, cluster state management, and more. By using the Spring Cloud framework in platform development, developers can focus on business-related functional logic and improve development efficiency. According to the microservice framework, function expansion only targets a specific service, without affecting other services, and enhances the overall availability and scalability of the system.

3. Data Utilization and Deployment Technology

In this study, containerized deployment is used for platform deployment, which is a technology that encapsulates applications and their dependencies in containers and allows them to run consistently across different environments. The use of container deployment can simplify the process of deploying applications, allowing developers to deploy applications to the production environment faster. Additionally, it can improve the portability of the application program, enabling it to run on different operating systems and hardware platforms.

When it comes to selecting a container deployment technology, the platform utilizes the Podman container engine, which can be used to create, run, and manage containers. Compared to other container engines, Podman does not need to run daemons, so it can be better integrated with the security policy of the system. Podman uses the Linux namespace to isolate the container from the host operating system, making the container more secure. By using the Podman container engine for system container deployment, the system's development and deployment process is simplified, its hardware compatibility is improved, and its migration and maintenance are facilitated.

4. Efficient Data Retrieval Technology

When searching for unstructured text content such as disease descriptions and disposal operations, the traditional SQL LIKE operation is inefficient because it is not suitable for large-scale data and only supports basic pattern matching, so it cannot perform advanced text analysis. The system utilizes Elasticsearch as a search engine, enabling the search, analysis, and exploration of a large volume of detection and monitoring data. This facilitates the comprehensive life-cycle management of platform detection and monitoring data, as well as efficient full-text search. Elasticsearch uses reverse indexing technology, and its basic idea is to take each word in a text record as a keyword and associate the keyword with the text record containing it. During the system's operation, Elasticsearch synchronizes the data from the database, utilizes the word segmentation controller to segment the relevant sentences, and then stores the weights and word segmentation results in the database. Later, when the user searches for data, the results are ranked and scored according to their weight, and finally, the returned results are presented to the user.

5. System Platform Interface Optimization Technology

The platform utilizes the React framework to optimize the display of the user interface and enhance the user experience. React is an open-source JavaScript front-end framework for building web-based user interfaces. Compared to other front-end frameworks, React uses a virtual DOM mechanism to make page rendering more efficient. It also applies a component-based development mode to page development, making the code more modular and easier to maintain. Meanwhile, React uses the architecture design of one-way data flow to reduce code coupling. In addition, the React community offers numerous open-source components, making it easy to learn and use the developed user interface.

In the bridge visualization display, WebGL is used to connect the multi-dimensional bridge data with the three-dimensional model. WebGL is a technology for rendering 3D graphics in a web browser that can be used with HTML5 through the JavaScript API. The system uses WebGL technology to display BIM visual models of bridges and tunnels. Based on this, users can interact with the visual models in various ways, such as rotation, scaling, translation, and clicking, thereby comprehensively viewing the multi-dimensional information of bridges and improving the system's usability.

Main functions

The platform supports batch import, timing synchronization, visual display, and long-term storage of structured and unstructured data from different sources, as well as statistical analysis of data across time and structural dimensions. It provides platform support for predicting disease trends and evaluating the state of metro civil engineering facilities. The functional architecture of the platform is illustrated in Fig. 5.

1. Data Import

Based on the standard data files of various types, the platform supports batch import of different data types. The collected data includes a basic information ledger, monitoring and testing data, safety assessment reports, and more. Based on the data sources, the monitoring data can be categorized as fixed online monitoring data, on-site small-scale instrument inspection or manual inspection data, and mobile large-scale equipment inspection data.

2. Data Storage

The relational database MySQL is used for storing structural data such as metro civil engineering facility tests and basic ledgers. Health monitoring data can be considered time series data, which is arranged in a time sequence and has the characteristics of a large amount of data, more writing and less reading, and more statistical indicators. The system uses the TDengine time series database to store monitoring data. Besides, the system utilizes the FastDFS distributed file system to store attachment files, such as test reports, disease pictures, and other unstructured data.

3. Data Management

Based on the confirmed monitoring items, including settlement observation, convergence (horizontal and vertical), horizontal displacement, mid-span deflection, layered settlement of soil, groundwater level, and combined with the calculation methods for various monitoring data, an automatic calculation module for monitoring data is constructed to automatically calculate the change, previous cumulative change, current cumulative change, deformation rate, and early warning level.

The rules for division and naming of the structure, fields, and methods for third-party testing and monitoring data entry are clarified. This standardizes the operational procedures for third-party testing and monitoring projects at the data level and forms data standard documents to provide operational guidelines for future projects. Additionally, the

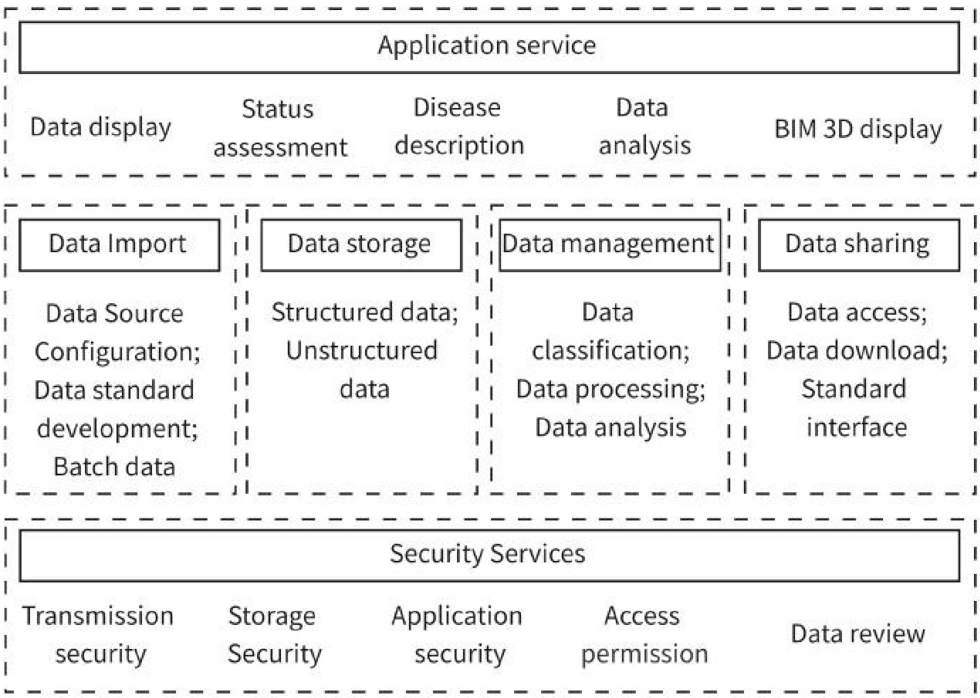


Fig. 5. Platform's functional architecture

standardized data structure lays the foundation for the subsequent construction of the standardization and visualization platform.

The collected data is classified, and different modules of the system platform are created to realize the corresponding functions. The system platform mainly includes six modules: comprehensive information management, basic information management, monitoring information management, detection information management, safety assessment management, and system management. The comprehensive information management module is used to display data comprehensively. The basic management module is responsible for maintaining metro structure information. The module for monitoring and detection information management as well as safety assessment is used to maintain all monitoring information, detection information, and safety assessment information under the condition of perfect basic information. The system management module is responsible for maintaining the information of each unit and user.

4. Data Sharing

Different management rights are assigned based on different roles to achieve visibility differentiation for modules and pages across various units and departments. The construction of the system platform meets the needs of management units and achieves the standardized integration and visual display of basic information, detection information, monitoring information, safety assessment, and other information about the bridge and tunnel structure. This provides a collaborative operation platform based on industry standards for management units and third-party units, improving the data management quality of management units and enhancing operation and maintenance efficiency.

5. Security Services

The server side of the system deployment is a private cloud server, which ensures that the information stored, used, and transmitted will not be leaked to unauthorized users or entities, and will not be tampered with by unauthorized users. It also prevents authorized users from improperly tampering with the system and information. With sufficient backup data storage space and a standardized backup control interface, the system platform achieves standardized management of system backups, supports backup requirements for different types of data, and does not affect the system's application during backup. Based on this, the system platform not only meets the basic requirements of data storage and backup, but also supports data recovery. Data can be recovered under different faults and unexpected situations.

6. Application Service

In the entire data management process of "import-storage-management-display", various functions such as data display, disease treatment suggestions, trend analysis, state evaluation, and comprehensive display are realized. This provides platform support for efficiently utilizing detection and monitoring data. The complete process management of data is illustrated in Fig. 6.

Using the historical detection data of a specific bridge as an example, both structured and unstructured data, such as photos, will be processed according to established data standards to transform non-standard data into standardized data. Subsequently, the data will be imported into the system platform mentioned in this paper. This has enabled the digital storage and retrieval of historical detection data, as well as the ability to conduct queries and analyses using various dimensional filtering criteria. Based on this, 2D and 3D data visualization can be achieved by integrating with maps, BIM, and other hosting platforms (Table 1).

Application case

Based on the research results of data standardization, a component-level database for metro bridges and a pile number-level database for metro tunnels have been built, providing a unified structural database for the analysis and application of subsequent detection and monitoring data.

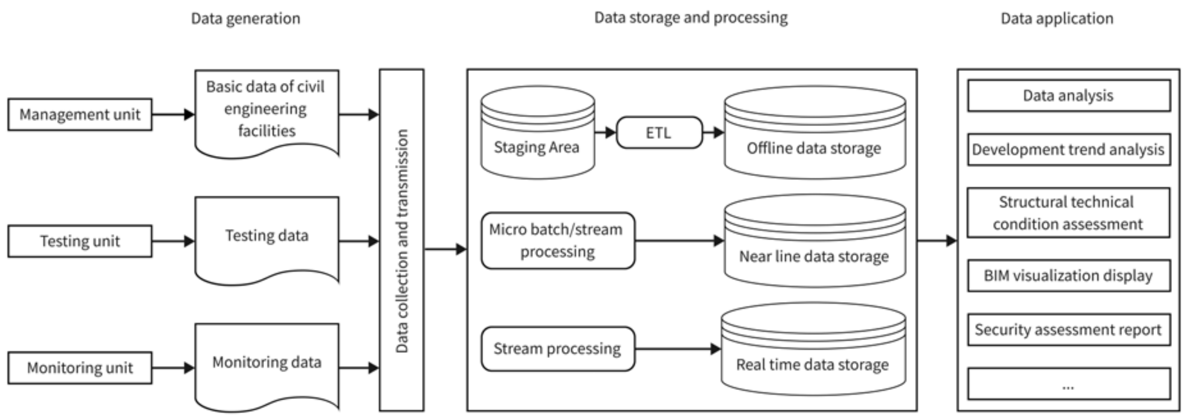


Fig. 6. Complete process management of data

Table 1. **Schematic diagram of data processing and display**

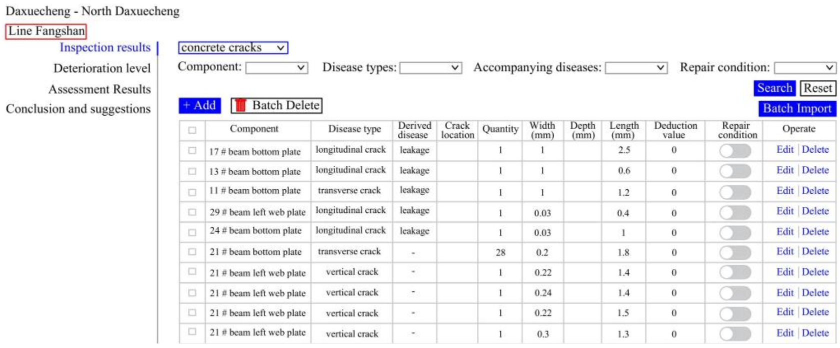
1. Inspection report

Fig. 1 MI6 Aging cracks on the surface

Fig. 2 MI7 Aging cracks on the surface

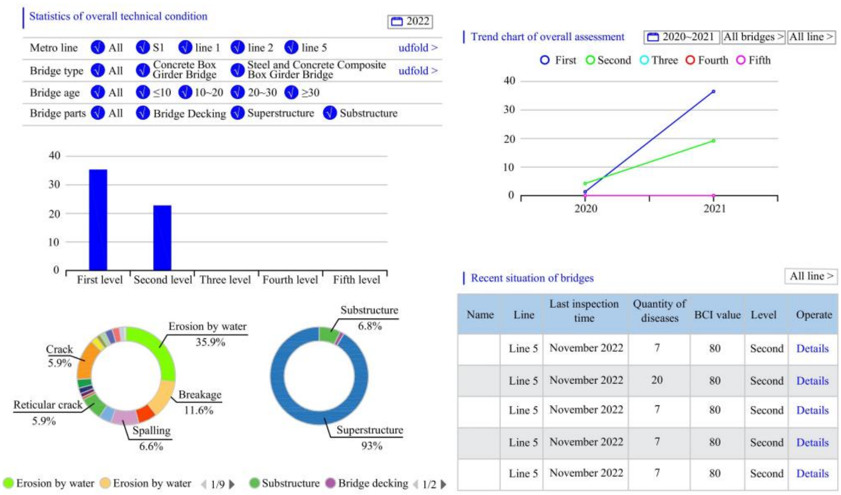
No.	Stay cables	Disease type	Disease description
9	MI6	Aging cracks on the surface	Long surface aging cracks on the PE sheath
10		Scratch	One point like scratch appeared at 41.25m from the bottom
11		Scratch	One scratch appeared at 44.5m from the bottom, about 4cm in length
12		Scratch	One scratch appeared at 37.5m from the bottom, about 3cm in length
13	MI7	Aging cracks on the surface	Long surface aging cracks
14		Scratch	One scratch appeared at 24m from the bottom, about 4cm in length
15		Scratch	One scratch appeared at 32.75m from the bottom, about 6cm in length

2. Data standardization processing



Component	Disease type	Derived disease	Crack location	Quantity	Width (mm)	Depth (mm)	Length (mm)	Deduction value	Repair condition	Operate
17 # beam bottom plate	longitudinal crack	leakage		1	1		2.5	0		Edit | Delete
13 # beam bottom plate	longitudinal crack	leakage		1	1		0.6	0		Edit | Delete
11 # beam bottom plate	transverse crack	leakage		1	1		1.2	0		Edit | Delete
29 # beam left web plate	longitudinal crack	leakage		1	0.03		0.4	0		Edit | Delete
24 # beam bottom plate	longitudinal crack	leakage		1	0.03		1	0		Edit | Delete
21 # beam bottom plate	transverse crack	-		28	0.2		1.8	0		Edit | Delete
21 # beam left web plate	vertical crack	-		1	0.22		1.4	0		Edit | Delete
21 # beam left web plate	vertical crack	-		1	0.24		1.4	0		Edit | Delete
21 # beam left web plate	vertical crack	-		1	0.22		1.5	0		Edit | Delete
21 # beam left web plate	vertical crack	-		1	0.3		1.3	0		Edit | Delete

3. Data display



Name	Line	Last inspection time	Quantity of diseases	BCI value	Level	Operate
	Line 5	November 2022	7	80	Second	Details
	Line 5	November 2022	20	80	Second	Details
	Line 5	November 2022	7	80	Second	Details
	Line 5	November 2022	7	80	Second	Details
	Line 5	November 2022	7	80	Second	Details

The bridge structure defines the component information of a specific bridge based on standardized splitting and naming rules, and all component information of a specific bridge can be quickly entered through an Excel spreadsheet. The tunnel structure is defined according to the pile number, and the detection and monitoring data is associated with the pile number of the tunnel structure.

The data types for all detection and monitoring items in the system platform are classified. Data types such as “text”, “number”, “option”, “option + text”, and “image” are sorted and configured according to field requirements. Let us consider the “concrete crack” detection item in the tunnel as an example. According to standard documents, the “crack location” field is composed of “part + pile number + pile mileage range + specific location”. The data type for the part and specific location is “option + text”, the data type for the pile number is “option”, and the data type for the pile mileage range is “number”. During the development process of the system platform, corresponding functional modules are designed based on the data types of each component, achieving convenient operation and standardized management during the input process (Fig. 7).

A standardized data import template has been designed for each detection and monitoring item in the system platform. It organizes the components of each field under a specific detection item and monitoring item in a table format in batches. It parses each column of the list using Python scripts and matches the components of each field with specific rules to achieve batch import of data standardization templates (Figs. 8 and 9).

Fig. 10 demonstrates the metro overview interface displayed on the home page of the system's comprehensive information management module. This interface provides an intuitive display of the distribution of metro lines, as well as basic information such as the number of metro lines, the total mileage of lines, and the number of stations. Furthermore, it allows querying the number, length, and corresponding proportions of bridges, tunnels, and roadways. The system features a user-friendly interface and practical functions, enabling the electronic management of metro line information.

Fig. 11 illustrates the data visualization interface of the system's comprehensive information management module. The visualization page displays the geographical location of a single bridge or tunnel, the BIM model, bridge components, detection data over the years, various data statistics, and more. By clicking the model, you can view the disease status of individual components.

Fig. 12 presents the interface for data chain analysis. The data chain analysis interface enables statistical analysis of both the temporal dimension and the structural dimension. Analyses can be conducted by selecting the structure type, data type, disease type, and line. Meanwhile, this interface supports the export function for both images and data.

In addition to the functional interface shown in the figure, the system platform also provides functional interfaces such as bridge evaluation, tunnel evaluation, comprehensive information

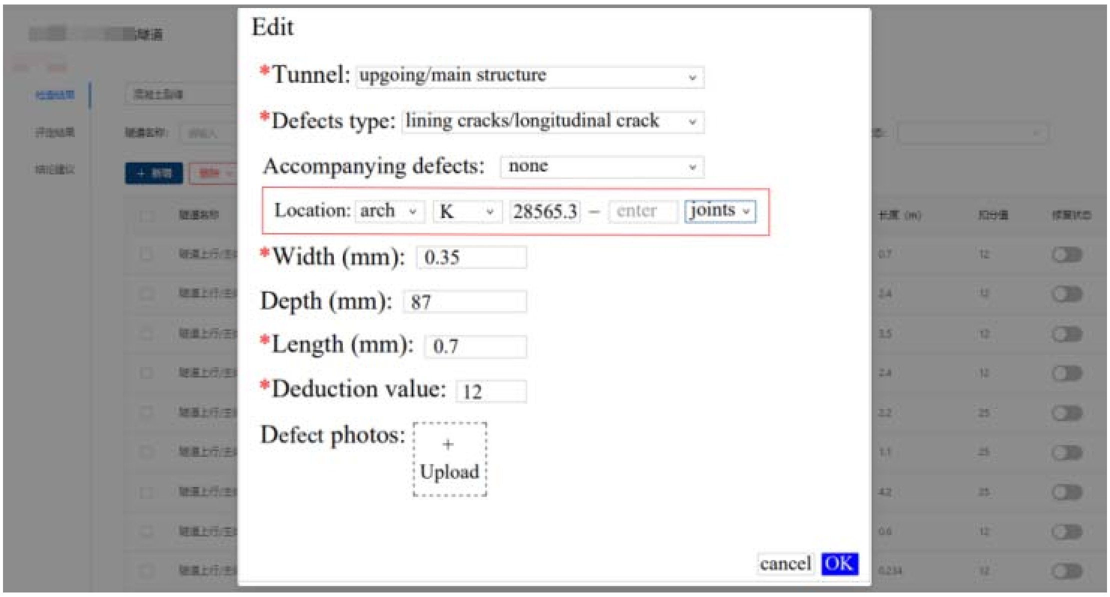


Fig. 7. Editing of tunnel detection result information

Fig. 8. Entry fields for batch data import

1	Tunnel direction	Structure type	Defects type	Accompanying defects	Defect location	Defect location/K	Defect location/Pile A	Defect location/Pile B	Specific location	Width/ mm	Depth/ mm	Length/m	Deduction value	Picture number
2	down	Main structure	Lining cracks/longitudinal cracks		left sidewall	K	1638.6		0.5m from the bottom	0.25	63	1.2		Picture1
3	down	Main structure	Lining cracks/longitudinal cracks		left sidewall	K	1639		0.4m from the bottom	0.23	84	2.1		Picture2
4	down	Main structure	Lining cracks/longitudinal cracks		left sidewall	K	1731.6		0.6m from the bottom	0.28	64	2.1		Picture3
5	down	Main structure	Lining cracks/longitudinal cracks		left sidewall	K	1753		0.5m from the bottom	0.25	60	2.1		Picture4
6	down	Main structure	Lining cracks/longitudinal cracks		left sidewall	K	1755		0.3m from the bottom	0.26	74	2		Picture5
7	down	Main structure	Lining cracks/longitudinal cracks		left sidewall	K	1758.2		0.7m from the bottom	0.27	63	2.4		Picture6
8	down	Main structure	Lining cracks/longitudinal cracks		left sidewall	K	1867.5		0.4m from the bottom	0.21	84	1.9		Picture7
9	down	Main structure	Lining cracks/longitudinal cracks		left sidewall	K	1871		1.2m from the bottom	0.31	98	1.5		Picture8
10	down	Main structure	Lining cracks/longitudinal cracks		left sidewall	K	1928		0.6m from the bottom	0.28	73	2.4		Picture9
11	down	Main structure	Lining cracks/longitudinal cracks		left sidewall	K	1930.2		0.3m from the bottom	0.31	67	3.2		Picture10
12	down	Main structure	Lining cracks/longitudinal cracks		left sidewall	K	1931.5		0.8m from the bottom	0.25	72	1.5		Picture11
13	down	Main structure	Lining cracks/longitudinal cracks		left sidewall	K	1932.4		0.5m from the bottom	0.23	83	1.7		Picture12
14	down	Main structure	Lining cracks/longitudinal cracks		left sidewall	K	1935		0.0m from the bottom	0.3	71	2.8		Picture13
15	down	Main structure	Lining cracks/longitudinal cracks		left sidewall	K	1945		1.0m from the bottom	0.25	63	2.2		Picture14
16	down	Main structure	Lining cracks/longitudinal cracks		left sidewall	K	1945.5		2.0m from the bottom	0.23	68	2		Picture15
17	down	Main structure	Lining cracks/longitudinal cracks		left sidewall	K	1953.1		0.5m from the bottom	0.32	52	2.2		Picture16
18	down	Main structure	Lining cracks/longitudinal cracks		left sidewall	K	1958		0.5m from the bottom	0.35	100	4.2		Picture17
19	down	Main structure	Lining cracks/longitudinal cracks		left sidewall	K	1979.5		0.2m from the bottom	0.23	79	4.3		Picture18
20	down	Main structure	Lining cracks/longitudinal cracks		left sidewall	K	1981.2		0.7m from the bottom	0.31	72	3.5		Picture19
21	down	Main structure	Lining cracks/longitudinal cracks		left sidewall	K	1980		0.5m from the bottom	0.35	102	6.5		Picture20
22	down	Main structure	Lining cracks/longitudinal cracks		left sidewall	K	2006		0.7m from the bottom	0.25	64	2.1		Picture21
23	down	Main structure	Lining cracks/longitudinal cracks		left sidewall	K	2086.5		1.2m from the bottom	0.31	75	0.3		Picture22
24	down	Main structure	Lining cracks/longitudinal cracks		left sidewall	K	2178		0.7m from the bottom	0.43	82	2.6		Picture23
25	down	Main structure	Lining cracks/longitudinal cracks		left sidewall	K	2267		0.4m from the bottom	0.49	97	1.9		Picture24
26	down	Main structure	Lining cracks/longitudinal cracks		left sidewall	K	2276		0.0m from the bottom	0.3	88	3		Picture25
27	down	Main structure	Lining cracks/longitudinal cracks		left sidewall	K	2331.2		0.7m from the bottom	0.24	74	1.4		Picture26
28	upgoing	Main structure	Lining cracks/longitudinal cracks		right sidewall	K	1735.4		0.4m from the bottom	0.3	87	2.6		Picture27
29	upgoing	Main structure	Lining cracks/longitudinal cracks		right sidewall	K	1745		1.6m from the bottom	0.34	75	Reticulum cracks		Picture28
30	upgoing	Main structure	Lining cracks/longitudinal cracks		right sidewall	K	1791		1.0m from the bottom	0.26	84	1.9		Picture29
31	upgoing	Main structure	Lining cracks/longitudinal cracks		right sidewall	K	1792		1.2m from the bottom	0.34	75	1.7		Picture30
32	upgoing	Main structure	Lining cracks/longitudinal cracks		right sidewall	K	1861.4		0.7m from the bottom	0.3	86	2		Picture31
33	upgoing	Main structure	Lining cracks/longitudinal cracks		right sidewall	K	1928		1.4m from the bottom	0.37	79	2.2		Picture32
34	upgoing	Main structure	Lining cracks/longitudinal cracks		right sidewall	K	1931.6		0.5m from the bottom	0.34	90	2.3		Picture33
35	upgoing	Main structure	Lining cracks/longitudinal cracks		right sidewall	K	1946.5		0.4m from the bottom	0.23	45	3.5		Picture34

Fig. 9. Batch import template

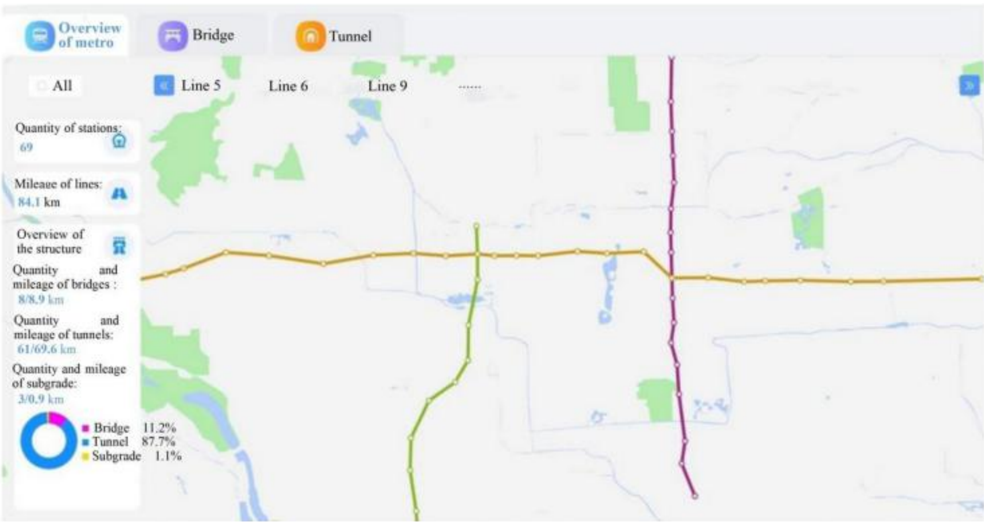


Fig. 10. Home page display

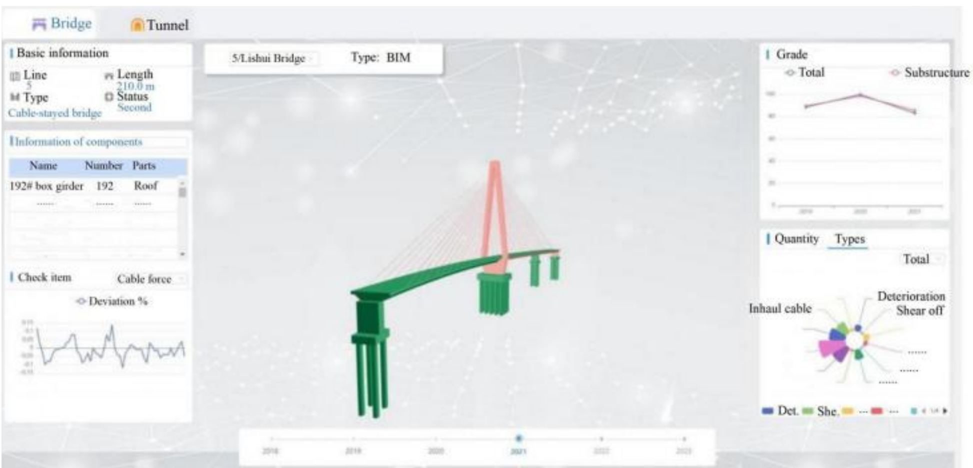


Fig. 11. Data visualization display

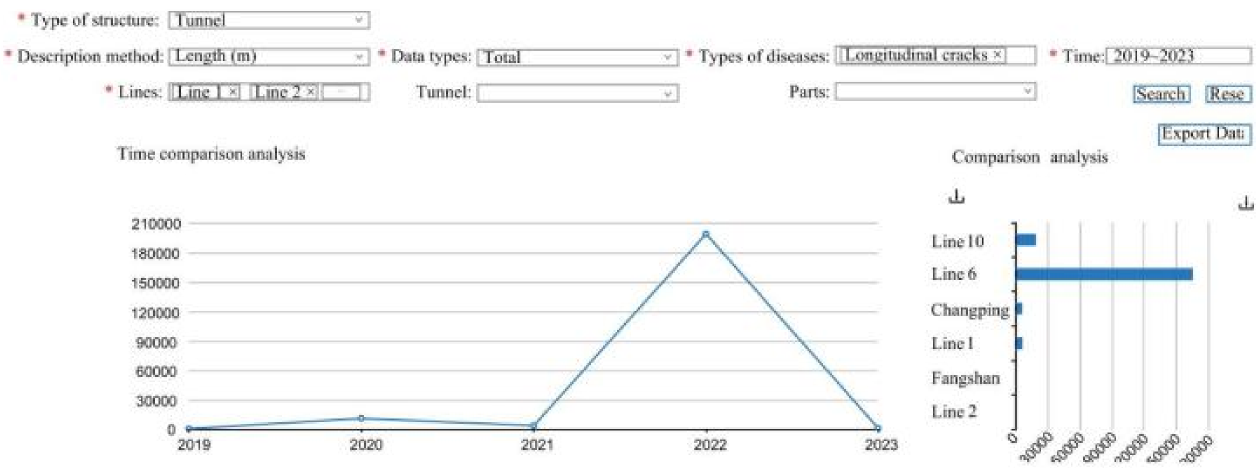


Fig. 12. Data chain analysis

query, site management, line management, structural management, monitoring engineering management, testing engineering management, safety assessment engineering management, and system management.

In summary, the platform for standardizing and visualizing monitoring and testing data for metro civil engineering facilities, addressed in this paper, has successfully implemented batch uploading, comprehensive management, and integrated analysis of multi-source data. By dividing system role permissions, it is possible to effectively satisfy the requirements of various roles, scenarios, and functions.

Conclusions

In order to meet the requirements for monitoring, testing, data asset management, automatic access, and intelligent analysis of metro civil engineering facilities, this paper designs and implements a third-party testing and monitoring data standardization and visualization platform for metro civil engineering facilities. The platform provides standardized batch data import, data classification storage, and data management and sharing functions. On this platform, standards for uploading third-party detection, monitoring data, and test data are established. This helps to solve the serious issue of data isolation between existing systems, establish a structured database, and effectively utilize multi-system data for comprehensive analysis.

The integration of detection and monitoring data has been achieved. Meanwhile, multi-source data fusion analysis and comparison across projects and intervals are realized in combination with massive standardized detection and monitoring data. This provides powerful data support for the whole life-cycle management of later facilities.

The platform has been in operation since 2022, and such information as testing and monitoring data, as well as basic information ledger from 2019 to 2022, has been imported. This confirms the feasibility of the platform.

Further research directions

1) Expand the scope of standardized data management and strengthen the processes for data standardization management, particularly focusing on data collection to ensure the integrity and effectiveness of the collected data.

2) Create a diversified and comprehensive data display page to enable such functions as structural detection cycle warning, auxiliary analysis of detection cost, disease tracking, and key information warning. Assist management personnel in visually viewing and quickly analyzing the health status of civil engineering facilities.

3) Study conventional-style parameterized modeling techniques for bridges and tunnels, and complete BIM modeling for the entire lines of bridges and tunnels, thereby providing a model foundation for the rich and comprehensive application of BIM visualization.

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ИССЛЕДОВАНИЕ ПЛАТФОРМЫ СТАНДАРТИЗАЦИИ И ВИЗУАЛИЗАЦИИ ДАННЫХ МОНИТОРИНГА И ИСПЫТАНИЙ ГРАЖДАНСКИХ ОБЪЕКТОВ МЕТРОПОЛИТЕНА НА ОСНОВЕ БОЛЬШИХ ДАННЫХ

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Аннотация
Введение: на межпроектном и межрегиональном уровнях с целью получения надежных данных для управления гражданскими объектами метрополитена на протяжении всего жизненного цикла проведены анализ и сравнение данных из нескольких источников с учетом обширных стандартизированных данных обнаружения и мониторинга. **Цель исследования** — интегрировать данные обнаружения и мониторинга в отношении мостов и тоннелей метрополитена и решить проблему значительной изоляции данных в существующих системах и различных блоках. На основе больших данных и технологии Интернета вещей в данной работе исследуется стандартизированный формат загрузки, хранения, обработки, обмена и других видов управления данными обнаружения и мониторинга в отношении мостов и тоннелей метрополитена. Кроме того, разработана платформа стандартизации и визуализации сторонних данных для мостов и тоннелей, обеспечивающая интеграцию данных обнаружения и мониторинга. В ходе исследования использовались следующие **методы**: теоретический анализ и разработка системы ПО. **Результаты:** практичность и реализуемость платформы были проверены на практике.

Ключевые слова: гражданские объекты метрополитена, платформа больших данных, обнаружение и мониторинг, стандартизация данных, комплексный анализ.