Design of Chongqing Inspection Data Center Based on Cloud Native Technology Architecture

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Abstract. In the present work, we constructed the Chongqing Municipal Inspection Data Center leveraging the cloud native technology architecture. The system was designed as a regional medical inspection data management center, focusing on centralized management of medical inspection data access, comprehensive data quality assessment, intra-laboratory and inter-laboratory quality control management, cross-hospital access for physicians, inspection result mutual recognition, duplicate inspection reminders, and public query services for big data. Secure processing and real-time analysis were employed to achieve real-time sharing and service visualization of medical inspection data across multiple platforms and locations in Chongqing. The system features advantages such as resource elasticity deployment, agile application, and trustworthy security. It has been deployed and operated online across the entire city, providing information support to address concerns regarding difficulties and costs associated with medical treatment, thereby alleviating the economic burden on patients. Through multidimensional and multi-faceted data applications, the multiplier effect of inspection data is fully leveraged, continuously empowering disease monitoring and emergency response efforts.

Keywords: Cloud Native, Big Data, Microservices, Inspection Mutual Recognition

1 Introduction

In order to implement the requirements of building a "fastest system deployment, minimal investment cost, optimal practical effect, and maximum data sharing" as part of the Digital Chongqing initiative[1-3], based on the Chongqing Smart Disease Control Cloud Platform[4], a Chongqing Municipal Inspection Data Center has been established using cloud-native technology architecture. It supports the mutual recognition of inspection results among medical and health institutions at all levels in the city, as well as infectious disease monitoring, early warning, and emergency response efforts, and

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has been deployed and operated online across the entire city, achieving significant application effects.

2 Overview of Cloud Native Architecture

Cloud native is a method for building and running application software that fully leverages the elasticity deployment and distributed technology advantages of cloud platforms, reshaping the entire software lifecycle to support faster innovation, better user experiences, stable and reliable user services, efficient development efficiency, and resource utilization [5-7]. Cloud native technology, with "application" at its core, focuses on how applications can better utilize the characteristics of the cloud environment. Unlike conventional applications that are simply migrated or refactored to run on the cloud, cloud native is an application architecture approach that fully leverages the advantages of cloud computing in the design, implementation, deployment, delivery, and operation of applications. It is based on core technologies such as microservices and containers, establishing a set of cloud native technical architecture systems [8-9], as shown in Figure 1.

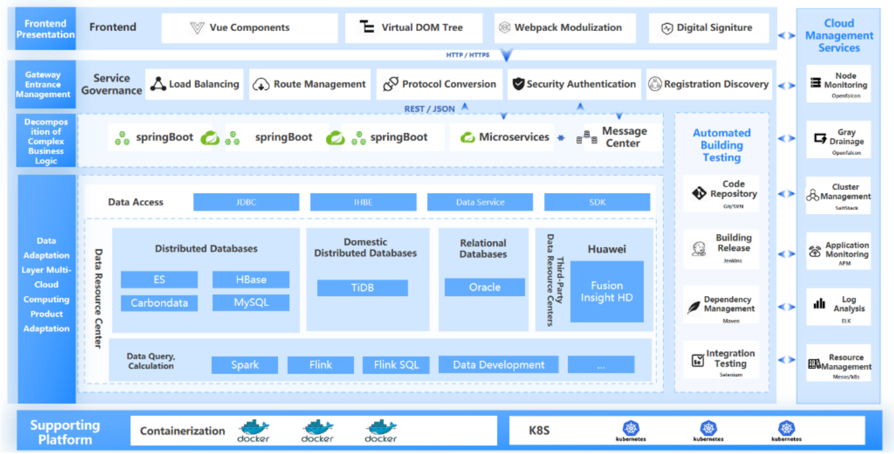

Fig. 1. Cloud Native Technology Architecture

To meet the various application scenarios such as standard management, data collection, data quality control, data sharing, report retrieval, proactive reminders, and others, and to mitigate the impact of changes in each scenario on the overall application while enhancing its scalability, a cloud-native microservices approach was adopted for the design and development of the application. This approach involves separating the technical aspects and services of each business scenario, enabling business modules to interact through agreed-upon interfaces. It ensures that business modules are relatively independent and can be modified without affecting each other, thus facilitating easier business expansion within the architecture. By identifying common business requirements, shared business demands were refined and abstracted into reusable core capabilities that could be shared across different scenarios. Through the use of services, backend business resources were transformed into user-friendly capabilities at the front end.

To address the frequent changes in business requirements and effectively support high concurrent access in various scenarios, a cloud-native one-stop DevOps development management and Docker containerized deployment approach were adopted. This enabled rapid iterations, ensuring smooth transitions from requirement gathering to software design, development, testing, and secure deployment into production environments. Prior to service division, automation tools and environments were established to expedite all repetitive tasks including creation, development, testing, deployment, and operations. This automated toolchain facilitated tasks such as compilation, building, testing, and integration, minimizing human errors and simplifying the development, operations, and management costs associated with the increasing number of microservices.

3 System Design

3.1 System Architecture Design

Based on the overall framework of the "1361" Digital Chongqing initiative [10], the Chongqing Inspection Data Center inherits the characteristics of the previous disease control information systems in Chongqing and is divided into five layers: infrastructure layer, data collection layer, data storage layer, data calculation layer, and application service layer [11].

The infrastructure layer is built on the communication transmission "One Network" and computing storage "One Cloud" provided by the Digital Chongqing Government Cloud Platform. It achieves unified scheduling and management of underlying hardware resources and constructs unified computing, storage, and network resource services.

The data collection layer utilizes a stream computing framework to collect real-time inspection result data and laboratory internal quality control data, and periodically collects inter-laboratory quality evaluation data. This efficiently supports services such as inspection result mutual recognition, infectious disease monitoring and early warning, and public query.

The data storage layer stores data obtained through data integration and calculation. Different databases such as MySQL, TiDB, and Doris are used according to different application scenarios to provide daily services such as routine queries, massive retrieval, and big data statistics.

The data calculation layer, based on the MapReduce parallel computing model and big data analysis engines, integrates and calculates massive data, supports diversified data transformation, and supports heterogeneous interaction of multiple types of data sources. It establishes data models for various types of data and provides robust support for data applications.

The application service layer provides various types of applications for users and scenarios, such as laboratory quality control, data collection management, inspection mutual recognition rate, and analysis of reasons for non-recognition on the management side; cross-hospital access and duplicate inspection reminders on the hospital side; infectious disease pathogen monitoring and emergency response access services on the disease control side; and inspection result query services for the public.

The system architecture is depicted in Figure 2.

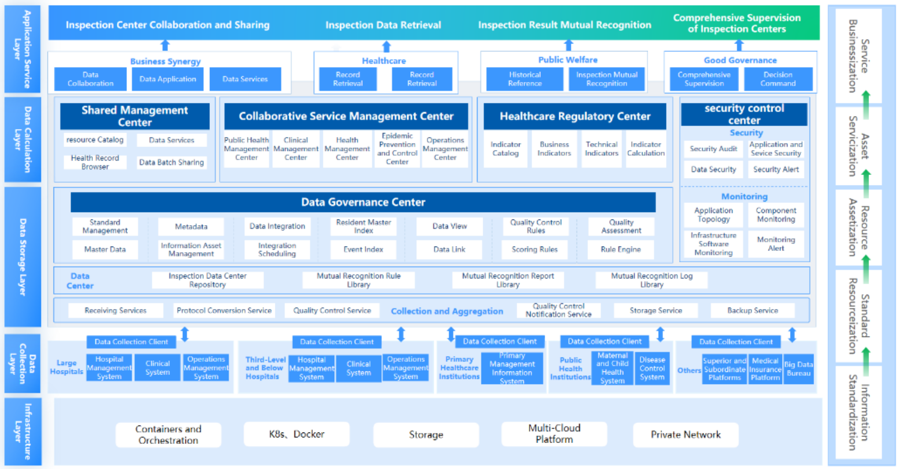

Fig. 2. System Architecture Design

3.2 Data Architecture Design

The data architecture of the Chongqing Municipal Inspection Data Center consists of three layers: the data collection layer, the data governance layer, and the data service layer:

Data Collection Layer: It corresponds to data from various business systems, with main data sources including third-level hospitals, secondary hospitals, community service centers, township health centers, community service stations, and village health clinics.

Data Governance Layer: This layer collects data from various sources into the platform to form a data resource repository. Within the data resource repository, data is categorized into Data Warehouse Detail (DWD), Data Warehouse System (DWS), and Application Data Source (ADS) layers based on usage.

Data Service Layer: It provides data services externally, including data gateways, data service APIs, and data resource catalogs.

The data architecture is depicted in Figure 3.

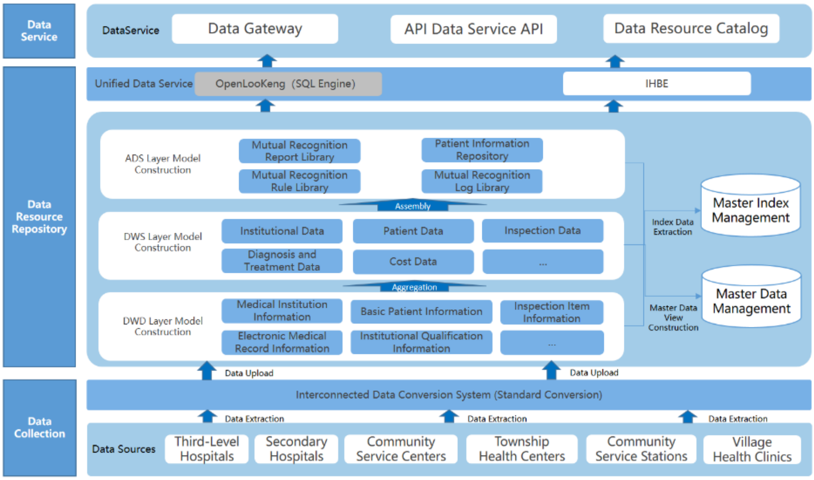

Fig. 3. Data Architecture Design

3.3 Business Process Design

Based on standards such as the "Metadata Specification of Health Information Dataset" (WS/T363-2023), the Chongqing Inspection Data Center expands to form the Chongqing Inspection Data Standard Dataset, establishing unified access service standards. By establishing data quality control rules and intra-laboratory and inter-laboratory quality control rules, the center controls data quality, performs data cleaning and governance, and forms the Inspection Data Center. The Inspection Data Center provides various query and sharing services externally through the business middleware. It establishes various microservices applications to provide convenient queries, result recognition, comprehensive supervision, and other cross-institutional, cross-level business applications [12-14]. The business process design is illustrated in Figure 4.

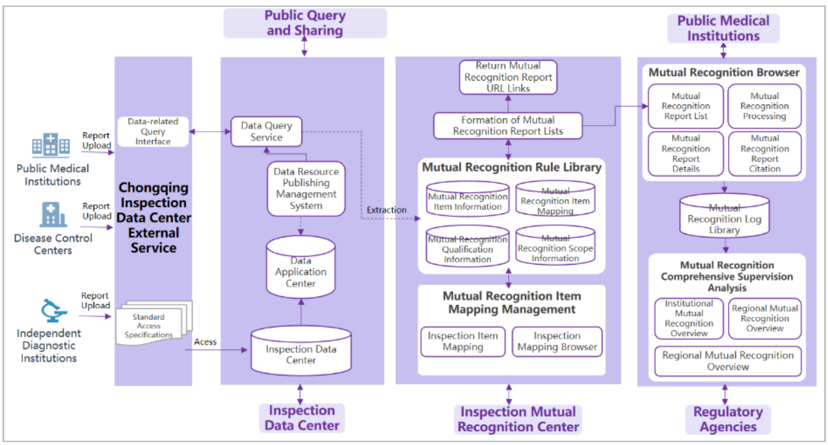

Fig. 4. Business Process Design

3.4 Network Data Security Design

The system is supported by the e-government extranet, the health specialized network, and the internet for data transmission services. Network security equipment is provided by the Digital Chongqing e-government cloud platform. The data center is deployed in the e-government extranet area. System users are divided into internet users and health specialized network users. Internet users connect to the data center through network operator links, while health specialized network users connect to the data center through firewalls and secure isolation gateways provided by the e-government cloud platform. For the security of data center hosts, important database servers use master-slave dual-machine hot standby and perform daily physical backups. Important business servers are deployed in clusters to fully ensure the security of the system network and data.

In accordance with the principle of "minimum and necessary," mobile query services are provided to residents. The data is encrypted and stored on dedicated front-end machines deployed in the e-government extranet area. These machines are connected to the data center through dedicated switches and provide services externally through HTTPS interfaces. An access whitelist is set up, allowing only specified servers to call. Data is shared with other applications and stored on dedicated front-end machines, and data retrieval is done through internal dedicated connections.

3.5 Personal Information Protection Design

In accordance with the requirements of the "Data Security Law" and the "Personal Information Protection Law", personal information is encrypted for storage and transmission, and frontend pages display desensitized information [15]. The data center conducts regular security scans to eliminate medium and high-risk vulnerabilities and prevent data leaks. Restrictions are placed on bulk data exports, and export logs are added, along with digital watermarks for traceability. Personal biometric features and personal information are stored separately. Users are subject to hierarchical authorization management, where ordinary users can only view data managed by their own unit and cannot bulk view or export sensitive user information. User login and operation logs are recorded according to the requirements of Level 3 Network Security Protection.

3.6 Software Function Design

The Chongqing Inspection Data Center mainly includes applications such as the formulation and management of data center standards, data collection, data quality control, data resource center, data resource publishing, inspection result mutual recognition, and public query services.

1) Standard Formulation and Management.
The system utilizes visualized standard management components to conduct visual management of data standards and exchange standards. The standard management components serve as tools for managing the storage model and exchange model of data

exchange. After model changes, they can provide script management and interface document management. Through the standard management components, we carry out the basic configuration of inspection data business classification, activity classification, management field pool, management field template, and data dictionary. The system then configures the exchange standards of the inspection data center as the basis for data collection, quality assessment, inspection result mutual recognition, and shared application analysis of the Chongqing Inspection Data Center.

2) Data Collection and Control.
Based on the unified standardized data access interface of the medical inspection data center, the system continuously collects real-time data from various levels and types of medical institutions and disease control centers across the entire city, including medical inspection result data, laboratory internal quality control data, and inter-laboratory quality evaluation data. It provides backend services such as data interruption monitoring, data standard coding, quality control standards, and data exchange monitoring.

3) Data Quality Assessment.
Based on the metadata of inspection result data, unified data standards, and quality control standards, a comprehensive evaluation method for data quality, including effectiveness, timeliness, logicality, standardization, completeness, and consistency, has been established. The system would then conduct comprehensive evaluations of the quality of inspection and testing data by institution, region, and time period.

4) Data Resource Center.

- Inspection Data Center Repository

Through services such as data collection and data quality assessment, the system would extract, clean, compute, and aggregate inspection data from all medical and health institutions to form the inspection data resource center, creating the inspection data center repository. Inspection information includes sample inspection report information, routine inspection result information, microbiological inspection results, bacterial identification results, drug sensitivity test results, unstructured inspection reports, and intra-laboratory quality control reports.

- Inspection Data Indicator Repository

Based on the inspection database, the system conducts multidimensional and multi-themed statistical analysis of inspection data. Statistical analysis results can be stored in the statistical analysis repository in the form of topics, providing business support for decision analysis services for management personnel. The system supports the automatic generation of trend analysis charts or evaluation report information.

5) Resource Publishing Center.
Information resource publishing and sharing serve as the bridge to integrate data sources

from different medical and health institutions. Relying on metadata information, the system integrates data into the data resource layer in full or incremental form. Through the data integration engine, adapt various data sources to realize the external release of various data types from the resource center, using a microservices architecture to provide various application API services externally.

Additionally, the resource publishing center employs comprehensive governance through a service gateway, supporting multiple protection and management mechanisms such as flow control, timeout management, blacklist management, circuit breaker management, message monitoring, heartbeat control, log control, service stub, service routing, and load balancing, ensuring the overall service's high performance and availability.

6) Inspection Result Mutual Recognition.
Based on unified recognition rules, recognition scope, and recognition timeliness, a closed-loop governance approach is adopted for data collection, including "pre-event" standardization of data standards and quality control standards, "in-event" online intra-laboratory quality control and inter-laboratory quality assessment, and "post-event" data quality evaluation. This ensures comprehensive governance of data collection. At the doctor's workstation, services such as inspection report viewing, repeated inspection reminders, reminders of mutually recognized projects, and reasons for non-recognition are provided. In the management end, applications for mutual recognition rule management and mutual recognition log management are implemented. Leveraging public service platforms such as "Yu Kuai Ban" and "Yu Kang Jian," services such as real-time inspection result queries and report downloads are provided to residents.

7) Data Sharing Services.
Focusing on the actual needs of infectious disease monitoring, early warning, and emergency response, the inspection data center standardizes inspection and testing projects included in pathogen monitoring across all levels of medical and health institutions. This addresses issues such as varying project names, testing methods, and inconsistent standards. It unifies project names and codes, forming a collaborative dataset for laboratory pathogen testing. This dataset provides inspection data support for infectious disease pathogen monitoring and emergency response, truly achieving the goal of "collecting once, using multiple times" for inspection data. In the future, it will further expand its applications in areas such as disease prevention and control and vaccine efficacy evaluation.

4 Application Effectiveness

4.1 System Online Operation Effectiveness

The Chongqing Inspection Data Center was launched and operational in October 2023, covering over 1300 institutions including the city's two levels of health committees, disease control centers, and medical institutions. It efficiently supported tasks such as inspection result recognition, public queries, and infectious disease monitoring and warning response. The platform has maintained stable operation.

As of March 2024, data from over 1300 medical and health institutions across the city has been integrated, totaling billions of inspection results. It provides cross-institutional retrieval and result recognition services for over 80,000 clinical physicians in various medical institutions, as well as mobile-based inspection result queries and report downloads for residents across the city. For the winter and spring seasons, focusing on key disease prevention and control, it has established a multi-pathogen monitoring system for respiratory diseases and real-time situational awareness analysis capabilities. For disease monitoring and emergency response, real-time sharing of pathogen monitoring and inspection result data is facilitated, providing real-time inspection result query services.

4.2 Standard Specification System Construction

Through the construction of the Inspection Data Center, Chongqing has established standards and regulations for inspection result recognition, including rules, scope, content, and validity period. Additionally, standards have been set for the collaborative dataset of pathogen detection, data exchange, and application programming interface (API). This effectively ensures the high-quality and sustainable development of data collection, business applications, and shared exchanges, providing a standard basis for the expansion of business applications and the development and utilization of data resources in the future.

4.3 Business Collaboration and Sharing Effect

Utilizing the foundational support system of the Chongqing Smart Disease Control Cloud Platform, organizational and user management have been unified, enabling business collaboration and data sharing among internal business application information systems. Services such as public queries, cross-system retrieval, and API interface services have been provided to facilitate access to and retrieval of inspection result data from medical institutions and disease control centers, as well as services such as cross-institutional retrieval, duplicate reminders, and result recognition.

4.4 Network Information Security Situation

By transitioning various security capabilities from simple product configurations to service-based configurations and redefining cumbersome security services from the perspective of business applications, necessary implementation logic has been abstracted. Full-scale testing has been conducted through the Network Security Level Protection (NSLP) evaluation. Cloud security services such as DDos network protection, bastion hosts, web application firewalls, host security, and network security policies have been utilized to provide strong support and security guarantees for the long-term normal operation of business and data flows.

5 Conclusions

The comprehensive advancement of Digital Chongqing has provided an opportunity for the construction of the Chongqing Inspection Data Center and the inter-institutional recognition of inspection results. The national "Management Measures for the Inter-recognition of Inspection Results of Medical Institutions" provides institutional support for the implementation of inspection result recognition. This paper explores the construction of the Chongqing Inspection Data Center based on cloud-native technology architecture. By implementing closed-loop governance of data collection through "pre-event" unified data standards and quality control standards, "in-event" online intra-laboratory quality control and inter-laboratory quality evaluation, and "post-event" data quality assessment, it supports cross-institution retrieval, duplicate reminders, and result recognition services for medical and health institutions. Through the improvement of administrative systems and recognition mechanisms, the concerns of medical institutions regarding the division of medical responsibilities are addressed, achieving 100% data access for all public medical and health institutions in the city, and encouraging third-party testing institutions and private enterprises with conditions to access. Through multidimensional and multi-party data applications, the multiplier effect of inspection data is fully realized, amplifying and superimposing the role of data resources, continuously empowering disease monitoring, public health emergency response, and other work.

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