

Research of new integrated medical and health clouding system based on configurable microservice architecture

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Abstract—The outbreak of a novel coronavirus in 2020 has brought great impact on the whole health system. Firstly, the existing medical system needs further integration and optimization to improve the abilities of supporting Internet of things and service-oriented cloud applications, thus optimize the overall system composition and operation, optimize the adjustment and application of various resources, and form a integrated disposal capacity, so as to prevent the medical system from being unable to deal with the extreme epidemic situation. On the other hand, with development of hierarchical diagnosis and collaborative medical system, higher requirements have been put forward for all levels of medical and health system, so that it can be effectively incorporated into the whole health system. At present, with help of service-oriented technology, combining service-oriented ideas and configuration methods, breaking through business barriers and integrating business functions is an important method to build multi-type application groups into cloud applications. Therefore, based on the application of configurable microservice system, this paper designs a new generation of smart medical and health system integrating various business functions, and provides corresponding solutions.

Keywords— novel coronavirus; configurable; microservice; smart medical and health system

I. INTRODUCTION

A. Challenges for the medical system from COVID-2019

The new epidemic situation caused by COVID-2019 in 2020 has brought great influence to all countries in the world. Both economic operation and social governance are facing the challenge of huge impact, especially for the construction and development of the whole medical system. From the perspective of the development of the epidemic situation, scarce of medical resources in the early stage of the epidemic caused a huge impact on the whole medical system in Wuhan, which also put forward high requirements for the upgrading of the medical system and the upgrading of the medical information system. During the procession of the epidemic, due to the relatively weak ability of base-level medical care and community medical care, lots of patients are always pursuing better hospitals such as Tongji Hospital, Union Medical College Hospital and so on. Then it makes the first-line hospitals extremely crowded. Therefore, we should try our best to improve the basic ability of hierarchical hospitals to provide overall medical service to avoid situation like this.

At the same time, with strengthen and development of new infrastructure, ability of distributed cloud services has been rapidly enhanced and it is possible to reshape the basic medical system by technical means and enhance the integrated medical information capability.

From the perspective of national policy trend, primary task of national medical system reform in recent years is to vigorously promote the development of primary health services. Key point of improving the hierarchical diagnosis and treatment system is to propose the "standard + system + service" mode. It includes promoting the transformation and upgrade of primary medical institutions such as clinics, diverting the pressure of large hospitals gradually, solving the problem of "difficult to see a doctor", and constantly injecting new ideas into the development of primary clinics. It can promote the balanced allocation of social medical resources, consolidate the foundation of hierarchical diagnosis and treatment, and boost the construction of the whole medical system to raise the overall medical level.

B. Development of Microservices Technology

With continuous development of service-oriented computing, SOA application era has undergone great evolution and it cover the fields from enterprise service bus to component-based business data platform. Many new technologies such as microservices have played a huge role in the construction of industry applications. Microservices and microservice architectures^[1 ~ 19] are the integrators of the whole service-oriented computing technology and they help realize the reorganization of kinds of applications. They help complete carding and construction of business logic from the perspective of servitization, realize the scalable combination of different granularity services and different forms of interfaces. They can also make existing systems expand to the new systems more flexibly and more compatible.

Based on common microservice architectures such as spring cloud, kubernetes and Dubbo, a series of excellent applications have been put forward in many industries, and many key achievements have been formed.

C. Support for integrated medical system based on microservice Technology

Microservice technology can effectively solve the problem of partition of various granularity, and it can help integration of various medical business logic. From perspective of impact of

epidemic situation this time, the core issues to be solved are listed as follows:

- ✧ Forming integrated primary medical treatment capacity to make the primary medical staff just need one system to complete daily work, covering medical, public health, family doctors and other daily business. They need not repeat input the same information times again and all the medical, public health, family doctor and other businesses can be integrated into the whole.
- ✧ Forming integrated medical collaboration capability for grass-roots units. Making different units can perform cross agency business collaboration such as referral to other hospitals, collaborative consultation, file sharing and reading, etc. And help them can exchange information with other departments such as medical insurance, drug administration, public security, civil affairs, poverty alleviation.
- ✧ Forming hierarchal medical abilities and maintaining balanced construction between grass-roots and all levels of medical institutions. By deployment of different clouding-based systems and construction of service-oriented applications, we can fully realize the combination ability of different levels of medical care, enhance the primary medical capacity and expand the coverage area.
- ✧ Forming integration expansion of the systems. From the perspective of development, it is necessary to establish a more comprehensive medical record sharing system to facilitate doctor diagnosis and medical business linkage and traceability. Furthermore, it is necessary to establish a medical public health integration platform so that general practitioners can carry out basic public health services in the process of receiving patients and it is necessary to provide two-way referral and remote consultation system interface in a larger range of medical service institutions to achieve or track diagnosis and treatment appointment and referral. And we need start from the perspective of traditional Chinese medicine, provide basic Chinese medicine services for the whole population; need pay attention to crowd diseases, provide targeted disease management services for patients with diabetes, hypertension and other diseases; need collect and report health supervision information and public health emergency information.

Therefore, based on microservice technology and microservice framework, this paper designs and implements a new generation of integrated medical system based on configurable microservice system, which can effectively realize the integration of these levels discussing above, optimize system architecture design, and support rapid and insensitive system performance expansion.

II. NEW GENERATION OF INTEGRATED MEDICAL SYSTEM BASED ON CONFIGURABLE MICROSERVICE SYSTEM

A. Functional requirements and framework design of new generation integrated medical system

New generation of integrated medical system should meet the demand for wide applications that using single data table to

support multiple institutions and meet the application characteristics of grass-roots units for multi-tenancy situations. It should provide large number of personalized setting functions, support personalized needs of different health institutions through parameter configuration in the cloud, provide multiple access methods such as client or browser for different end-users, to realize automatic installation and upgrade Level. At the same time, it is necessary to provide user-defined query functions to adapt to the sustainable development of business according to the continuous development characteristics of health management needs at all levels.

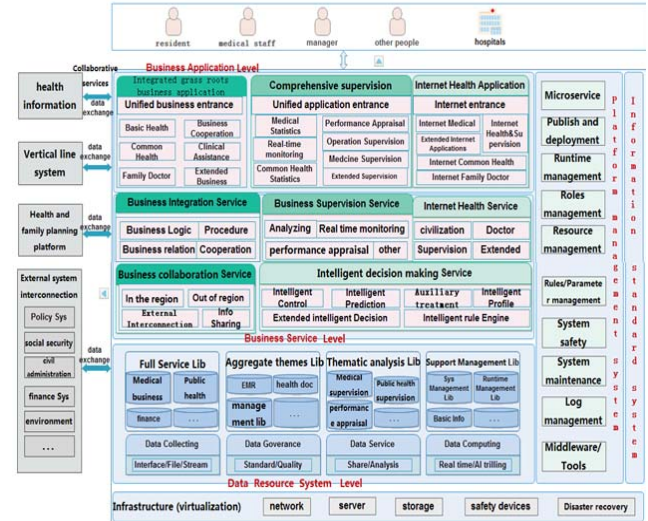


Figure 1. Internal design of scalable edge nodes

As depicted in Figure 1, the new generation of integrated medical system framework includes business application system, business service system, data resource system, platform support management system and information standard specification system. The five systems cooperate with each other and provide application and services based on Standard Specification as well as security guarantee for service organizations and objects based on microservice framework.

The framework realizes residents' health card, appointment registration, two-way referral, telemedicine, auxiliary diagnosis, rational drug using, sharing of electronic medical records, sharing of inspection results and corresponding Internet application services by making full use of the existing data resource and established business application services, so as to reduce the frame of the integrated medical system to avoid unnecessary cost and time cycle caused by repetitive construction.

The integrated medical system framework provides integrated business applications that support daily business of primary medical and health institutions. These business applications are constructed according to the unified standards and specifications, with unified application entrance, unified arrangement and application management mechanism.

We have established not only jumping relations between business rules and business data but also shared exchange mechanism with business collaboration. All business

applications are deeply integrated just like one. Furthermore, new generation of integrated medical system framework provides transformation standards and docking means for national, provincial and municipal vertical systems and other built information systems in using for primary medical and health institutions. By using docking and transformation ways, independent information systems of each sector can be integrated effectively, arranged unified to realize the integration of business.

The framework is able to establish association and intercommunication with the information systems or platforms of other departments, such as public security, social security, medical insurance, drug administration, civil affairs, finance, environmental protection and other departments, so as to realize cross department business interaction and data exchange to support the development of business services.

The framework provides services based on SaaS mode, solving a series of problems such as large number of medical and health service outlets at all levels, decentralized construction, too much self-management, non-sustainable operation and maintenance. Thus we can meet the application characteristics of grassroots using multi-tenant mode, support the personalized needs of different grassroots medical and health institutions, support multi terminal and multi type cloud access, and realize automatic installation and upgrading for terminal plug-ins.

Core of the framework system lies in the application of microservice architecture technology. By using microservice we can solve the problems of low system deployment frequency and deliver customer requirements quickly caused by high deployment cost. We can realize rapid function expansion, upgrade and flexible deployment, realize low-cost rapid expansion and elastic expansion of the system, reducing system risk and cost.

We extend standard spring cloud framework to complete the whole management through customed service construction and management, realizing service definition and management of business, circulation, interaction and other links, as well as realizing application of all the service-oriented system.

Through distributed cluster, multi-level load balancing and asynchronous message mechanism, the framework can improve concurrent throughput and response speed of the system, and meet the demand of high concurrent access. By using technologies of database cluster, sub database and sub table, read-write separation, master-slave replication and cache cluster, we realized massive storage and fast access of data, as well as seamless expansion and allocation of data space, so as to meet the needs of increasing data volume and accumulating types of institutions and users.

As depicted in figure 2 is the hierarchical structure of new integrated system. Kinds of common services and business services form the whole system by the microservices architecture and the basic modules as well as their interactions. All the microservices system is constructed on Spring Cloud framework and they includes:

- ✧ Service Provider, Spring Boot;
- ✧ Service Registering and Service discovery, Consul cluster supporting Sidecar mode;

- ✧ Load balancing service gateway, Keepalived + Nginx, realizing primary and standby architecture, real-time switching, and fail over;
- ✧ Service gateway and routine, SpringCloudGateway cluster;
- ✧ Load balancing for clients, Ribbon(embedded into service gateway);
- ✧ Fuse, Hystrix(embedded into service gateway);
- ✧ Service call, Fegin(embedded into Spring Boot);
- ✧ Service cluster monitoring, Spring Cloud Turbine(embedded into Spring Boot);
- ✧ Service communication and system integration, Spring Integration;
- ✧ Distributed configuring center, Consul cluster;
- ✧ Log collecting and analyzing scheme, FileBeat + Kafka + Logstash + ElasticSearch + Kibana;
- ✧ Data accessing, MybatisPlus;
- ✧ Static resource service, Nginx.

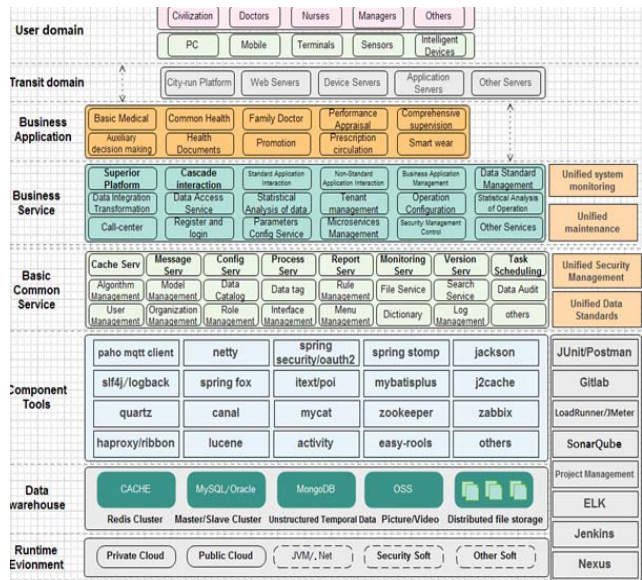


Figure 2. Hierarchical structure of new integrated medical system

B. Business application integration mode based on microservice architecture

In the whole system, the first core problem is integration of different business applications and we should implement data display, data entry and form submission under the same set of interactive UI. Moreover, we should support business logic, business process, business integration, business collaboration, data flow and access in an integration way while these services are loosely related themselves. These services can be developed, delivered, upgraded, deployed separately and they will suffer least affection when expanding functions as well as performance. Especially after the outbreak of the new crown epidemic, flexible integration of different levels, collaborative integration of different regions, functional integration of different businesses is all need to be defined and unified in a service-oriented way.

Service interaction mode 1: making existing business application system convenient for service transformation, and its front-end page using embedded menu or button form to call the unified business application service of new integrated medical system framework to realize business integration interaction or business integration.

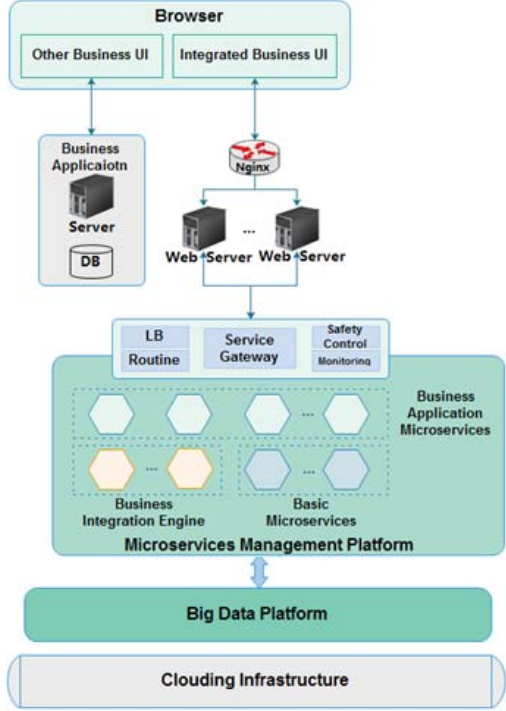


Figure 3. Service Interaction Mode 1

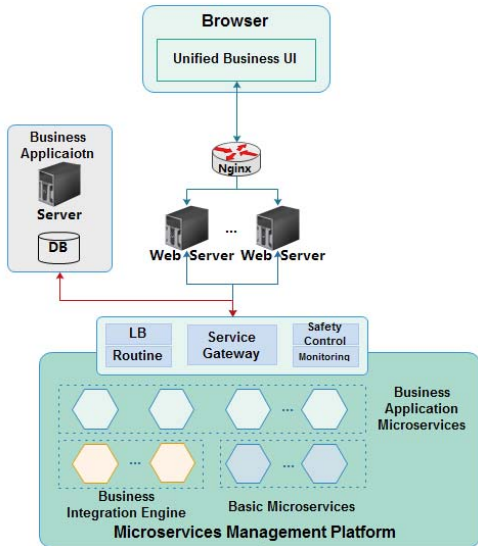


Figure 4. Service Interaction Mode 2

Service interaction mode 2: if existing business application system is not convenient for service transformation, the interface interaction mode is adopted to complete the service interaction activities through unified restful interface.

C. Design of business service system

We provide support for applications through business service system based on application services including five types of them:

- ✧ Business integration microservice set;
- ✧ Business collaborative microservice set;
- ✧ Business comprehensive supervision microservice set;
- ✧ Internet health microservice set;
- ✧ Intelligent decision-making microservice set.

The hierarchy of microservice architecture of the whole business service system is shown in Figure 5-6.

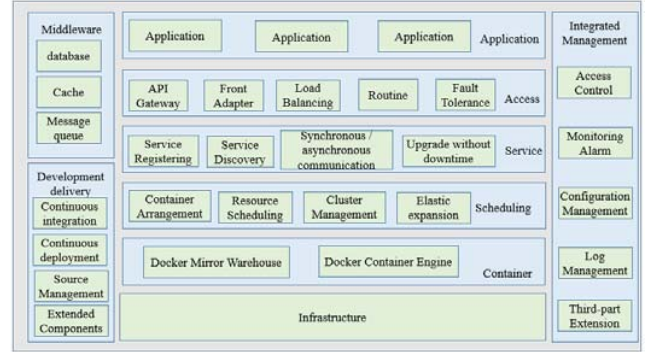


Figure 5. Business service system microservice architecture

Business applications access mode is designed according to the pattern in Figure 3 or figure 4. Mobile applications usually access the business microservices through mobile front-end adapter, while other types of accessing requests are dispatched through API gateway. We use docker container to oversee deployment or operation of applications as well as microservices, and use Kubernetes for the management including container scheduling, resource scheduling, elastic scaling, container cluster management and so on.

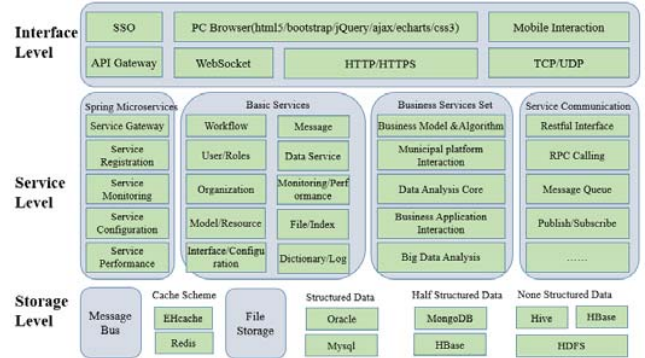


Figure 6. Business service level design and interface

D. Design of business integrated microservice set

Business integration microservice set provides direct business logic and process services for grass-roots integrated business applications. It is responsible for executing jumping actions for business association logic and business collaboration request distribution as well as according response tasks.

Each integrated microservice set has the same structure with accompanying functions, and provides integrated business services for some fixed grass-roots organizations with local

message queue and independent service library. By dispersing the business requests from different organizations to different microservices sets, the concurrent visits of grass-roots organizations are improved and they will get faster response. The integrated microservices set is divided into business logic services, business process services, business associated services and collaborative linkage services.

[1]. business logic services

They are designed to cover basic medical, public health, family doctor, clinical laboratory examination, regional electronic medical record, regional physical examination management, comprehensive management of institutions and other business logic services. It receives the request from the business application and executes the corresponding business logic. Different requests will trigger calling of these service separately.

[2]. business process services

According to the business rules, a series of activities that constitute the business process are controlled and scheduled to control the business data flow to the next correct person who oversees the business. Thus, we can realize the purpose that a business can be successfully completed by the cooperation of different individuals.

[3]. business related services

Core logic of these services is to take the diagnosis and treatment business as the traction to realize the correlation jump between different business points of medical and public health services. Design of business association process is as follows: extract the key identification in business data, compare and judge data according to business rules, find out the business page link and corresponding data associated with the requested business point, and display the associated business page with data by the front-end application interface.

[4]. collaborative linkage service

Collaborative linkage service is mainly used to share business services and exchange data between different medical units. When the request is two-way referral, remote consultation, image collaboration, remote health records retrieval of other cross agency, the collaborative linkage service distributes the request to a collaborative linkage service in the collaborative sharing microservice set, and the selected collaborative linkage service will perform the collaboration logic. At the same time, the collaborative interconnection request initiated by other organizations is will also be accepted by target organization and it will assign the request to a business logic service within its organization. Through collaborative linkage services, cross-agency, cross -department and cross-level business collaboration and data exchange can all be realized.

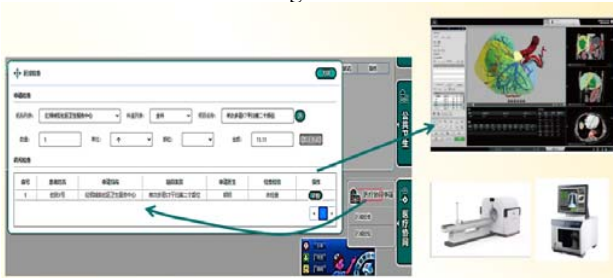


Figure 7. Collaborative linkage service Example

E. Design of business collaborative sharing microservice set

The business collaborative sharing microservices set consists of four types of microservices: intra-regional collaborative services, external collaborative services, external system interconnection services, and information sharing and retrieval services

[1]. Regional collaborative services

These services are responsible for the business collaboration logic among the institutions themselves under the framework of the new integrated medical system, and they establish a two-way collaborative linkage channel between collaborative institutions by connecting the collaborative linkage services of different institutions.

[2]. Collaborative services outside the region

These services are responsible for the collaborative interaction with the superior management platform to realize the two-way business collaboration between the grassroots institutions and the superior institutions under jurisdiction of the new integrated medical system framework. They realize the synchronous uploading of the grass-roots business data to the superior platform; accept the data access request from the superior platform; assign the request to other micro services, execute the data acquisition logic, and feedback the result data to the municipal platform.

[3]. External system interconnection service

These services are responsible for two-way interaction with external platforms or systems such as public security, social security, medical insurance and drug supervision. The data requests of external system are transmitted into the system through the external system interconnection service while the data request of the primary organization to the external system interconnection service is also assigned by the collaborative linkage service. They link to the external system interconnection service, and obtain the data, and the result data is returned to the requesting organization.

[4]. Information sharing service

It is responsible for obtaining the global subject data of the new integrated medical system from the aggregation subject database, including aggregated subject data such as electronic medical records, electronic health records, inspection results, etc. The structure and correlation of business integration microservice set and business collaboration microservice set are shown in Figure 8 below.

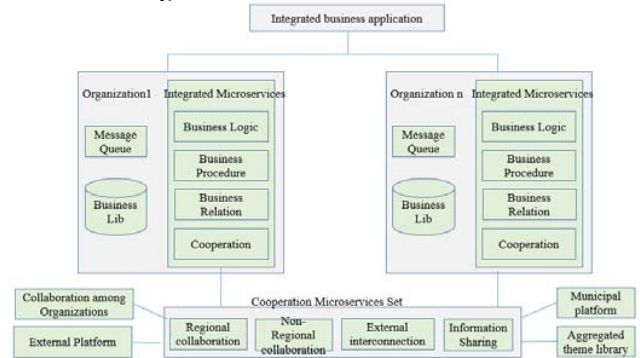


Figure 8. Business Integrated Microservices and Business Collaborative Sharing Microservice

Important core of business integration and collaboration is to establish the association between different types of businesses, which is completed through business association services.

As shown in Figure 9, business association services are mainly composed of interfaces, matchers, databases and user interfaces. The service interface is used to receive the query request from the page, which is implemented by spring-boot based applications. The matcher collects other business information (business number, name, page link, and related data) related to the unique ID of the requested business and the association rules configured by the system. The matching process can be carried out by the rule engine, which provides the configured management mode. Users can manually set the rules and specify a group of associated businesses for each business through the background.

Collaborative linkage service is composed of interface, transponder, database and user interface. The frame is as depicted in Figure 10.

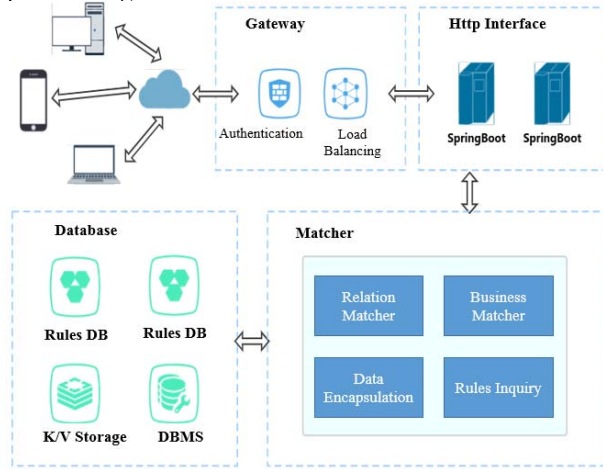


Figure 9. Business Association Services Framework

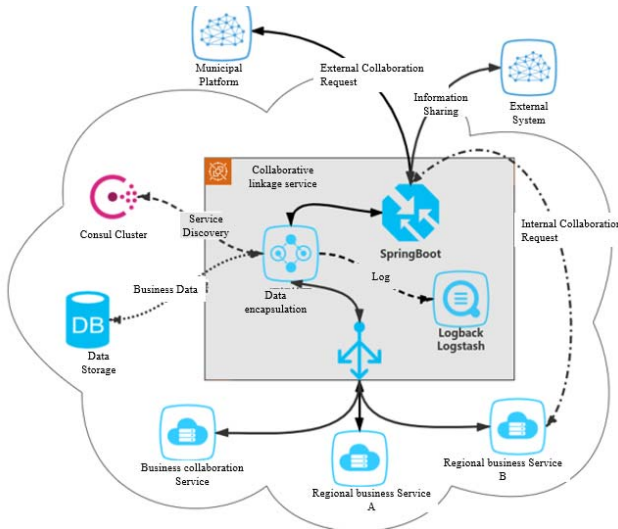


Figure 10. Framework of collaborative linkage service

After receiving the business collaboration request, the service interface sends it to the transponder for processing. According

to the collaboration direction, collaboration type and collaboration target, the service identification of the target is determined, and the business data (such as electronic medical record, medical insurance payment details, etc.) required for collaboration are collected and summarized. Finally, the request with its data are packaged and pushed to the target service. After receiving the request, the collaborative target makes response according to the type of collaboration: two-way referral, remote consultation, remote file retrieval, regional inspection, regional imaging, regional ECG or external information query.

F. Design of integrated business supervision service set

The supervision microservice set is a microservice set that provides services for integrated supervision application, including special statistical analysis service, real-time monitoring service, performance evaluation service, operation supervision service, etc.

Through the integration of unified and multi-form business views, different business information is aggregated. Based on different business access dimensions and information extraction, thematic expression will be formed. Combined with help of diversified presentation formats and report generation tools at the front end, we can operate business information with their display flexibly and fast. We can get intelligent chart, ad hoc query, intelligent early warning, and meet personalized requirements of comprehensive supervision.

Comprehensive query is carried out according to a variety of classification business classification methods (time, region, crowd characteristics, business characteristics and other different dimensions) to meet needs of different users. It supports feature dimension subdivision, such as query by time and son on. According to the characteristics of statistical data, it can be divided into query by year, query by quarter, query by month, etc.

According to the standard statistical caliber, the statistical summary reports (national statistics, ministry statistics, user-defined reports, etc.) mainly include real-time statistical analysis module, standard (or custom) report module, ad hoc query module, subject analysis module, etc.

[1]. Configurable thematic statistical analysis service

According to different supervision topics of medical service, public health, family doctor contract, medicine and health resources, the relevant data can be statistically analyzed, and other special statistical analysis can be extended. The service management is based on the configuration method. The system analyzes and sorts out the relevant business data of various topics, provides rich data query and statistical functions, and provides data support for macro policy formulation and management.

[2]. Real time monitoring service

Real time monitoring of key business of regional medical and public health, including outpatient visits, number of filing, number of contracts signing, average prescription fee, large prescription, average prescription fee, large prescription number, number of large prescriptions, number of high blood pressure cards, number of diabetes cards, etc. The monitoring indicators adopt configuration management method, which can be customized flexibly.

[3]. Performance appraisal service

Based on assessment index and assessment scheme, the objective and comprehensive evaluation of the primary medical institutions in the jurisdiction is realized. The assessment adopts the configuration management mode, users can customize and expand based on the template, and can also configure various assessment indicators.

[4]. Operation supervision service

This type of service is mainly provided to the management department for the regulatory authorities and community managers to view and supervise the business development in the region, and can also be provided to the third-party management platform in the form of service interface to meet its use.

G. Design of Internet health microservice set

Internet health microservices set provides service support for mobile Internet applications, realizes integration of online and offline business processes by using mobile Internet technology. The Internet plus medical system can enhance the public's experience and experience in the new integrated medical system framework. We support online booking, intelligent guidance, two-way referral, sign up service and family doctor's on-site service. Internet plus health service can satisfy the residents' online personal health information inquiry, medicine Information inquiry and health education, etc., "Internet plus prescription transfer", supports safe transfer of prescription between medical institutions and pharmacies, supports mobile payment in hospitals, medical insurance card payment and convenient business insurance claims, and realizes unified management of mobile end payment terminals.

H. Design of intelligent decision micro service set

According to business rules and knowledge, the intelligent decision-making microservice set can intelligently calculate the relevant data according to the according rules and knowledge, realize the intelligent decision-making function, and provide decision support for medical and health business with comprehensive supervision. They can provide intelligent auxiliary diagnosis and treatment, intelligent medical quality control, intelligent early warning or prediction, intelligent health portrait, and expand other intelligent services. A unique intelligent rule engine is established to help users design rules, apply rules, and modify rules, so that all grassroots application systems can share intelligent rule determination methods on demand, improve the accuracy and targeting of their own application management, support the configuration and customization of rules by application participants.



Figure 11. Intelligent decision micro service example

I. Data management and analysis service design

In this framework, there are various types of data, and ownership and transfer relationship of them are also different. As shown in Figure 12, the data is classified into management of total data or incremental data. At the same time, management of personalized data is realized through many fine-grained service instances in the way of one hospital one pool, which fully reflects the difference and flexibility of data management.

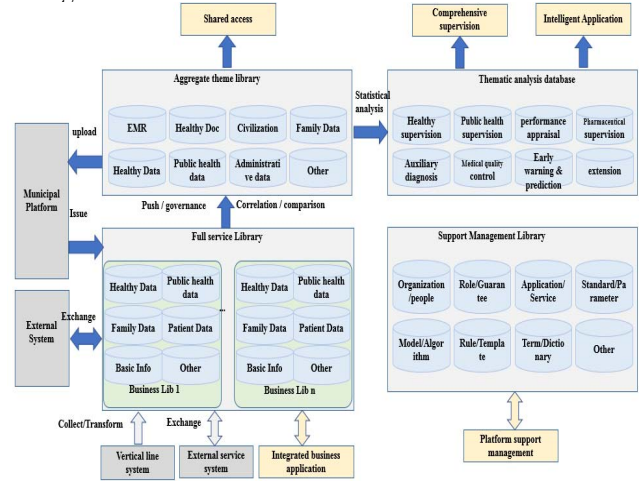


Figure 12. Data Management Service

As depicted in Figure 13 is according big data analysis service. The service realizes medical domain model, medical knowledge graph, intelligent learning and analysis method through plug-in mode. The data is cleaned, stored and processed according to the hierarchal structure. In the framework, the diversity of structured data, unstructured data and semi-structured data is fully considered, and various methods such as text are used to process and mine the data, so as to fully play the role of intelligence and auxiliary automation in auxiliary prescription, intelligent inquiry and other links.

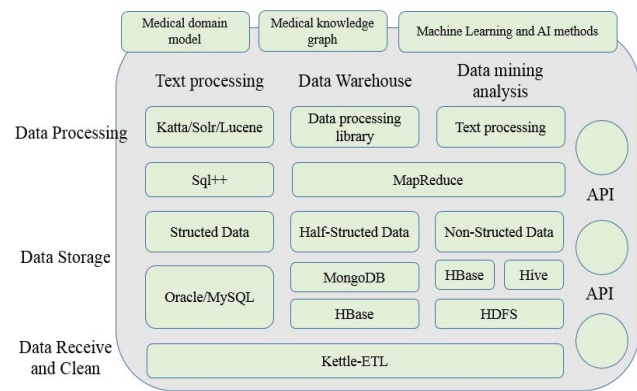


Figure 13. Big Data Analyzing Service

All this framework and according services have been used in several area and their hospitals gradually. It has improved efficiency of doctors as well as nurses and serviced lots of patients better.

III. CONCLUSION

The COVID-2019 disaster outbreak in 2020 will bring many new challenges to existing medical system. The medical integration management including business integration, regional integration and management integration has become key point to the upgrading and innovation of the new generation medical system. At the same time, microservices system plays an important role in different types of applications because of its flexibility, expansibility and business adaptability. Therefore, based on the framework of microservice, a new generation integrated medical system is designed and implemented in this paper. Through the hierarchical service construction mode, the multi-level application functions from business to collaborative management are realized. It provides a useful support for improving the new medical system under the new infrastructure technology and it has been successfully imported in similar construction of similar occasions. In future works, we will strengthen the system continuously and import more intelligent services to provide more comprehensive functions.

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