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An Ontology-based Approach for Data Integration in Regionally Interoperable Healthcare Systems

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Abstract：In order to best utilize the limited resource of medical resources, and to reduce the cost and improve the quality of medical treatment, we propose to build an interoperable regional healthcare systems among several levels of medical treatment organizations. In this paper, our approaches are as follows:(1) the ontology based approach is introduced as the methodology and technological solution for information integration; (2) the integration framework of data sharing among different organizations are proposed(3)the virtual database to realize data integration of hospital information system is established. Our methods realize the effective management and integration of the medical workflow and the mass information in the interoperable regional healthcare system. Furthermore, this research provides the interoperable regional healthcare system with characteristic of modularization, expansibility and the stability of the system is enhanced by hierarchy structure.

1 Preface

Nowadays, the healthcare information systems in most developed countries have stepped into a new era with the main characteristic that the large-scale and regionally integrated and Interoperable Healthcare Systems are developed and applied by many medical institutions. For example, the Strategic Health Information Network for Europe is conducted; researchers in Holland establish a National Switching Point by an integration platform so that the medical institutions can exchange patient's information safely and secretly; the Integrated Advanced Information Management Systems (IAIMS) project granted by National Library of Medicine in USA has realized the large-scale and integrated Interoperable Regional Healthcare Systems in the medical college of George Washington University and the medical center in university of Utah.

Recently, the cooperation of army and civilian for the demonstration project of medical service, which is one of the National Key Technology R&D Program of China: the demonstration project of Interoperable regional healthcare service, has started in Chinese PLA General Hospital. This project is guided by the modern service concept and takes advantage of advanced computer network technology in order to achieve the information sharing and system integration among levels of medical institutions by building the public service integration platform and operation mechanism for interoperable regional healthcare. This work will maximize the usage of limited medical resources, reduce medical cost and improve the quality of medical treatment by which the ubiquitous problem about few accesses, high cost and lack of order to medical treatment will be solved.

Interoperable regional healthcare system comes up with the development and requirement of medical and health service. Its nature and functions determine that it must be a large-scale computer network featured as an integrated system with several interconnecting sub network systems. Therefore the key technology is information integration. In this paper we will give both the methodological approach and technique solutions for information.

2 Aim and Requirement for regional and interoperable healthcare system

2.1 The aim of interoperable regional healthcare system

The aim of interoperable regional healthcare system lies in the maximum usage of medical and health resources by integrating important medical technologies and sharing the medical resource and information .That includes three specific objectives as follows:

- The new digital medical service pattern and service process standard with the complete modern medical supply chain system
- The interoperable regional healthcare sharing platform to achieve the unified dispatching, delivery and service sharing among tertiary medical institutes in certain area combined with the monitoring and evaluating system for the sharing services.
- Provision of services ,such as two-way referral, telemedicine imaging consultation, online reservation, mobile registration, online medical consultation, remote medical record and test result query ,online medication consultation and patient‘s following-visit ,in the community and hospitals of intermediate and advanced level.

2.2 The requirement for regional and interoperable healthcare system

The above mentioned objectives demand a sophisticated info-structure that features the following six core requirements:

- The integration of existing information systems of the medical institutions in the region for the capability of medical resource sharing.
- The integration platform of regional medical institutions for public information service to government, medical organization, community and citizen.
- The data center of medical information in the region as the main data source for the integration platform realizing the medical information sharing.
- A complete set of standard and regulations according to the situation of China for the integration and application of regional healthcare system to ensure the modularization and expansibility.
- The process and rules for the operation of regional and interoperable healthcare service platform to keep the system efficient and stable.

The development of the third party service guarantee including the medical delivery service ,for example the distribution and delivery of medicine ,instrument and testing sample ,online information service and community health service, which will lead to good social and economic benefits.

3 The Framework for Regionally Interoperable Healthcare System

Since the information of healthcare domain is diversified and dynamic because of the heterogeneous and distributed information resources and the large amount of daily updated data produced by many information systems from medical institution, the key problem for constructing regionally interoperable healthcare system is the efficient management of medical workflow and the effective integration of mass data resources. Therefore the modularization design and expansibility with the hierarchy structure are essential to this system.

3.1 The physical structure of regionally interoperable healthcare system

The physical architecture of regionally interoperable healthcare system is shown in Figure 1.

The health department is responsible for the medical data from each regional data center to monitor disease and alarm plague .Each regional information integration platform is composed of tertiary hospital, secondary hospital, clinics and community healthcare center by which different levels of medical institutions in a region are able to share the data from data centers and realize two-way referral and medical record lending. Meanwhile different regionally integrated information platforms can exchange the resource data and perform remote consultation.

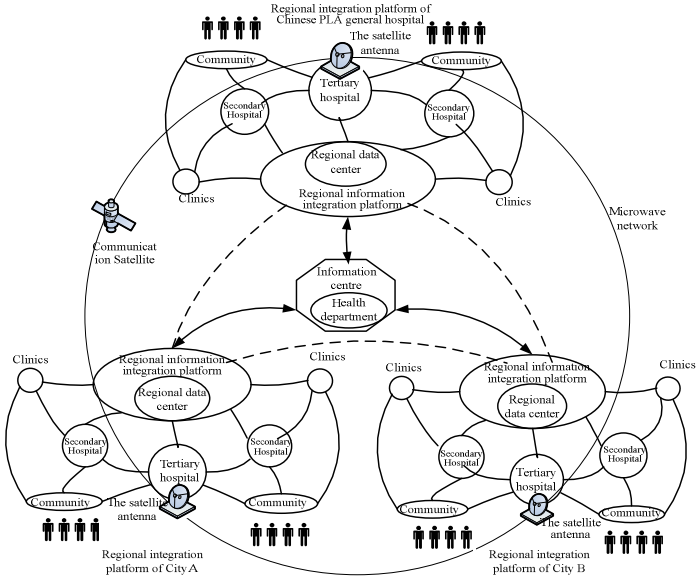

Fig. 1. The physical structure regionally interoperable healthcare system

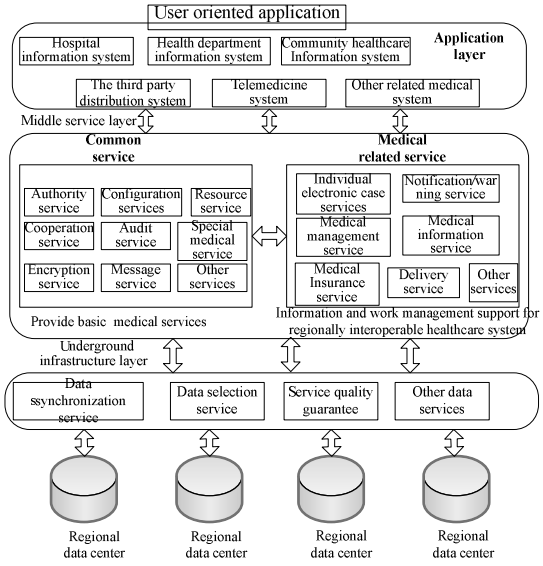

Fig. 2. The logical structure of regionally interoperable healthcare system

3.2 The Logical Structure of Regionally Interoperable Healthcare System

The regionally interoperable healthcare system adopts the hierarchically logical architecture [1] which includes data layer, underground infrastructure layer, middle service layer and user service oriented application layer. Each layer is modularly designed in a loosely coupled way as shown in Fig.2.

4 The information integration based on ontology

The aim of our regionally interoperable healthcare system, which requires the maximum usage of medical recourses, demands complete access to available medical information which is often heterogeneous and distributed .However, information sharing among different medical systems not only needs to provide full accessibility to the data but also requires the interoperability among these systems. The main problems caused by bringing together heterogeneous and distributed computer systems are summarized as semantic heterogeneity and structural heterogeneity [2].

Semantic heterogeneity refers to the variation of semantic meaning in medical information resources which will lead to the semantic conflicts and complication for data integration. Structural heterogeneity means that the same data will be described in different structures by different systems because of various application systems, DBMS and operating systems.

In our regionally interoperable healthcare system, we will take advantage of ontologies for the

explication of medical knowledge as a possible approach to overcome the problem of semantic heterogeneity, which will be discussed in 4.1 and the problem of structure heterogeneity will be solved by the use of XML based data integration together with data warehouse discussed in 4.2.

4.1Structure of ontology

In the realm of knowledge management, ontology provides both the theoretical basis and the applied methods to morph the different knowledge modalities to form a unified knowledge object since they can be used for the identification and association of semantically corresponding information concepts.

In our interoperable regional healthcare sharing platform, ontologies are used for describing semantic meaning of information source explicitly in order to solve semantic heterogeneity. There are three ways to employ the ontologies[2]: single ontology approaches, multiple ontologies approaches and hybrid approaches. We adopt hybrid ontologies in our research because (1) its implementation cost is reasonable; (2) it is flexible with the change of information source (3) comparing among ontologies is simple the usage of vocabulary common vocabulary.

Fig.3 shows the structure of hybrid ontology approach in which semantics of each information source is described by its own local ontology. A global ontology with the shared vocabulary is built up providing an overview of all the local ontologies and making comparison with them. We identify well-founded semantic correspondences between concepts from different ontologies based on the shared vocabulary in global ontology as the mapping approach for integrating semantic information.

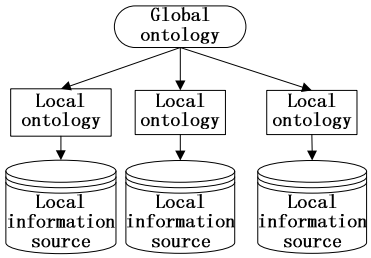

Fig. 3. The structure of ontologies for semantic information integration

4.2Ontology definition and representation

To construct the regionally interoperable healthcare sharing platform, we identify three levels of knowledge in ontology as follows according to the types of healthcare knowledge that directly contribute to the medical services:

(1) Operational knowledge represents the operational regulation and patterns of business process of each healthcare institution.
(2) Organizational knowledge concerns the organizational structure and policies exercised by a healthcare institution, patterns of organization's services and regulation.
(3) Social knowledge reflects the social and cultural norms of the overall medical service environment that influence the behavioral models of all involved humans.

These three types of knowledge are described both in the local ontologies and in the global ontology in Fig.3 to ensure the integrity of semantic information integration. With the introduction of norm and knowledge in different level, the ontologies will give a whole and explicit identification of concepts and regulations in various medical institution .We choose to use OWL to describe ontology for its particular roles in information integration and because it relies on XML schema data types. Furthermore, based on the hybrid ontology approach discussed in 4.1.1, the semantic heterogeneity will be solved for information integration.

4.3The service oriented web services for integration

The basic structure of medical information should provide the interface and logic to manipulate these data in a unified way based on the results of data integration. The service–oriented integration (SOI) combines the traditional integration object with open and highly flexible web services, and provides an abstract interface [3] through which medical information systems can interact with each other instead of by bottom protocol and user-defined programming interface specifying how the system communicates with other systems. The medical information is described in the form of services so that

other services can discover and select to interact and bind with them when they are running or being designed [4].

Since many of medical institution in China have established hospital information with good function, it is a high labor and resources consuming work and not feasible in the situation of China to develop a whole new medical information system based on HL7 and web services while discarding original systems [5, 6]. So the only solution is to modify on the basis of existing hospital information system in order to maintain their integrity. Web services can help to construct, parse and transport messages conveniently for existing heterogeneous medical information systems, no matter whether they are standard or not, which is a good way for data exchanging among different systems [7].

4.4 Data integration

4.4.1 The integration framework for data sharing among different hospital organizations

The hospital data integration is based on the technical results of IHE (Integrating the Healthcare Enterprise) which are based on the standards of HL7 and DICOM3.

IHE aims at establish a set of standard processes ,which are realized by DICOM, HL7 and other message systems, in order to integrate different systems. The Cross-Enterprise Document Sharing (XDS) is proposed in IHE in order to solve the problem of regional medical information sharing.

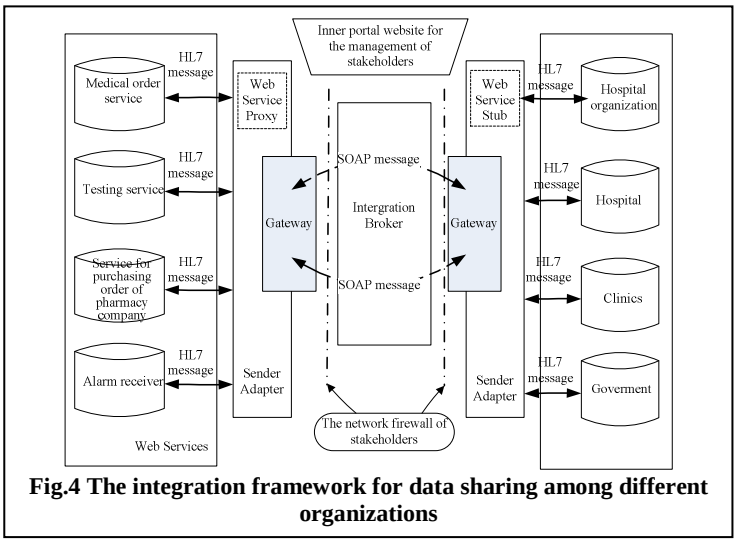

Fig.4 The integration framework for data sharing among different organizations

HL7 is the medical system integration standard based on messages and mainly used for data integration. Figure 4 illustrates an integration framework for data sharing among different organizations [8].

Based on the ontology method for heterogeneous information integration from semantic level, we also present a HL7 based virtual database to realize the data integration which will be discussed in the following sections.

4.4.2 The HL7 based virtual database

The main source of data in actual hospital institutions for integration is relational database [4].Comparing with ontology approach to solve the semantic heterogeneity, the XML based data integration of hospital information systems provides a unified interface of data manipulation for practical application to deal with structural heterogeneity. XML schema serves as the global data model and XQuery is the unified transformation language for operation of data source. The integration result is in the unified form of XML which can be shared by application programs and systems [5]. As Fig.4 shows, together with ontology for semantic integration, the XML based virtual database of hospital information system is composed of four parts: query processor, integration service manager, semantic part and structural part.

1) The query processor manages the query request and control request respectively according to user's data request and return the results in the form of XML

2) The integration service manager manages the metadata, local view and global view of the data source for integration by the definition of integration task and cooperates with global ontology and

query processor.

3) The semantic part deal with the semantic heterogeneity by ontologies .This part gets the XML based source information from structural part and provides knowledge to integration service manager.

4) The structural part concerns the structural heterogeneity .The Wrapper is responsible for interacting with low-level data source, packaging heterogeneous data source and operating the relational database using standard SQL with the aim of realizing the transparency of data location and visiting.

The data integration provides the basis for middle service layer by sharing the information. However the shared data must be transported to medical information systems in a proper way.HL7 is suitable for the mass information exchange among hospitals, insurance company and super administrative departments. DICOM ,which simplifies the exchange of medical image and promote the development of teleradiology system and picture archiving and communication system(PACS),make it for possible for the integration with other medical application systems such as HIS and RIS owing to its openness and interconnection.

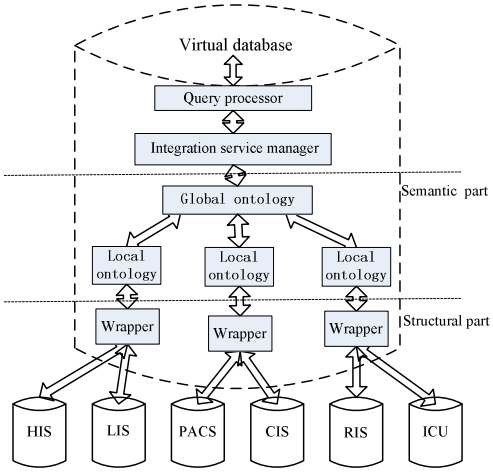

Fig. 5. The structure of the XML based virtual database for hospital information systems

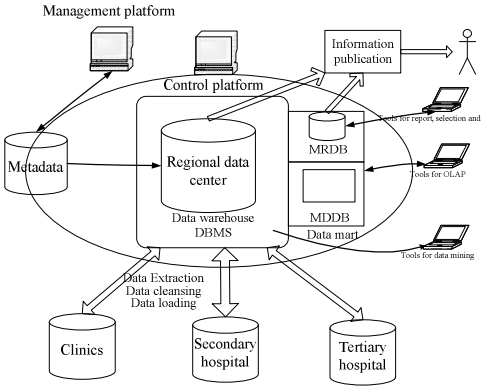

Fig. 6. The structure of healthcare data center

5 Conclusions

As one of the National Key Technology R&D Program of China, the demonstration project of interoperable regional healthcare service was launched in China in 2007 and a regional medical data center is established based on the research results of the project, as shown in Fig.6.This further validated the feasibility of our1method which provide new pattern of modern medical service and guide the establishment of regional medical informationization.

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