Practical Applications of Ontology-based Multi-agent Systems for PPHIIS

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Abstract—**This study presents an ontology-based and multi-agent system for PPHIIS assessment, an integrated information system for the health of People's Police (PPHIIS) was investigated, and an ontology model was designed and implemented to represent the health domain knowledge combined with the agents' cooperation, the SO^{s}RCE-ontology model not only solved semantic problems about heterogeneous data but also enabled medical staff to extract detailed medical information more efficiently. Meanwhile, a level of abstraction at which we envisage integrated systems carrying out cooperative work by inter-operating globally across networks connecting police, hospitals and terminals was offered by the multi-agent view.**

Index terms—**multi-agent, heterogeneous, shared, PPHIIS, SO^{s}RCE-ontology.**

I. Introduction

Integrated information system plays an very important role in nowadays' information age, to different information systems, architecture and programming languages are probably different, owing to which data redundancy and data inconsistency emerge. Moreover, the design of each database differentiates among each information system, thus leading to the hackneyed phenomenon- "information island". In order to reduce the expenditure, improve the reuse rate and optimize the existing legacy system, making data format unified and resource shared is a quite vital issue. With the rapid development of the internet, group applications such as network audio, video broadcasting, distribution of health information and interactive simulation etc, are emerging. L.MA gave the latest reviews about PHDIS: to integrate the existing transaction (e.g. vehicles, case review, immigration, OAS, CAS) into the owned one urgently, and achieve the goal of information interaction, we analyzed the model of the integrated system with XML [1]. J.L verified the validity for constructing the ontology of QA by the experiment of reusing ontology in medical domain, and the average F-value of extraction and classification reached 82.8%[2]. FU.N showed a comparative study on data model about data integration, in the source system, without data integration, users cannot be provided with good risk control and decision support[3]. To solve the semantic problem of data integration, Cristiane. A used a specific method to make research into ontology-based system[4]. J. Han and Z. He studied xml-oriented data model on the web[5-6], X. Yuan brought mediation-based System called "HDIS"[7], although xml afforded a certain degree of heterogeneousness in the grammar of data from different data sources, it cannot solve the problem about semantic heterogeneousness. As a philosophical concept, ontology has most meanings, Studer R defined ontology as a shared conceptual model of an formal specification[8]. According to the field dependence, Guarino N divided ontology into four categories as follows: top-level ontology, domain ontology, task ontology, application ontology[9]. Ontology is referred as a describing knowledge modeling tool in semantic level, which establishes the foundation for knowledge sharing across applications[10]. As a conceptual model for the specific domain, ontology aims at capturing domain knowledge in a generic way and provides a commonly agreed understanding about the domain. Ontology provides a common vocabulary of an area and defines the meaning of the terms and the relations between them with different levels of formality because of the imprecise and uncertain Information in applications[11]. Currently, links between ontologies are just beginning to be made. In the foreseeable future, the web of links between documents, databases, and programs, using definitions like the ones above, can provide a new level of interaction. For example, the World Health Organization Classification of Neoplastic Diseases[12] could become a model, with links to other diseases, databases, and clinical trials. New software tools are being developed for mapping and linking the terms between different ontologies; for using ontologies in the markup of web sites and databases; and for capturing semantic data about images. New search technologies are under development to exploit ontological and other Semantic Web technologies, as well as to extend the capabilities of Semantic Web languages to allow more complex information to be expressed, for example, representing how a particular process might change over time, or how a set of web-accessible programs could be automatically combined[13].

The integrated information system for the health of People's Police (PPHIIS) demands the representation of semantic information defined by knowledge experts. In this paper, Ontology is applied as a standard formalism to represent semantics. According to the definition,

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ontology expresses the structure and the meaning of concepts and relationships of the medical domain. Generally, ontology has the following characteristics:

·Open and dynamic

·Scalable and interoperable

·Ease of maintenance

·The corresponding fields in the semantics are identical

·Coherent context

Of particular notes are some of the first demonstrations of Semantic Web “agents” that can integrate the information from web pages and databases and can pass them to programs for analysis and query processing[14]. L. Zhang applied ontology-based modeling approach to clearly represent the emergency logistics knowledge for decision optimization and multi-agent cooperation, meanwhile, an emergency logistics ontology representation model and ontology repository with OWL was developed through a five-layer modeling approach, this model allowed multiple agents to share a clear and common understanding about the definition of logistic problem and the semantics of exchanged logistics knowledge[15]. Most of the current development is going on separately from the enterprise. This situation parallels that of the development of the original Web, where scientists largely served as customers and users of Web technology, rather than helping to evolve the technology toward the needs of their fields. In fact, much of the information technology research investment has gone into technologies that could not compete with the Web and that ended up less used than the commercially available Web technology[16-17].What is worth mentioning is: Stanford University developed TSIMMIS adopting a self-describing data model OEM (Object Exchange Model) which not only offered strong support for heterogeneous data integration but also provided the data integration system with a tool for automatic generation of components for integrating heterogeneous data.

In this paper, SO^{s}RCE ontology model was brought initially by studying the original concept of ontology, then a new framework of PPHIIS about data management was put forward, and finally PPHIIS extended the overall model of the framework.

II. Methodology

For ontological modeling, OWL was frequently used in the process of description. It offers a standard set of operations, the process of ontology’s construction generally includes two steps:

·Step One: Define an adequate formal template for knowledge representation.

·Step Two: Define the template about the content.

In PPHIIS, agents are based on the framework for data recovery & data processing, the framework not only makes the system much safer but also promotes the management. M. Peng brought multi-agent system (MAS) which simulated the interaction between human beings and the terminal. In order to improve the efficiency of collaboration and distribution of the system, social relations in MAS was introduced to study the trust model, the trust model based on MAS Social Relationship Agent-TMS is essential for MAS to achieve the greatest benefit. Social relationships are suitable for large multi-agent system and quantitative for the relationship which is produced by the natural relations in the cooperation process[18]. Relying on cooperative agents for the integration of distributed data, we realized the process of data integration. In this way, several agents individually achieved their functions in PPHIIS, and finally the interaction between police and the database was converted into the interaction between the agents. Source models which need to be represented in conceptual model in order to provide scalable and flexible data integration of autonomous and heterogeneous data sources do help in integrating distributed data sources, ontology is the explicit specification of conceptualization and can handle the semantic heterogeneity of the local sources[19]. Quynh-Nhu Numi Tran synthesized a methodological framework for ontology-centric AOSE which incorporated the key concerns for MAS development and addressed the concerns about reuse and interoperability to improve system extensibility, interoperability and reusability issues, the framework was targeted at developing ontology-based multi-agent systems (MAS) in heterogeneous environments and it takes into account ontological commitments of agents throughout the analysis and design processes[20]. Figure 1 is the structural design of PPHIIS. The agent-based model could not only achieve the relevancy, intelligence and inheritance between different heterogeneous databases but also meet the security needs. Furthermore, not only could police update the medical information with one handheld terminal, but also medical staff could completely extract the historical data by sharing the database. To solve the problems of heterogeneousness, the ontology model is used to describe the relations between the concepts in the resource.

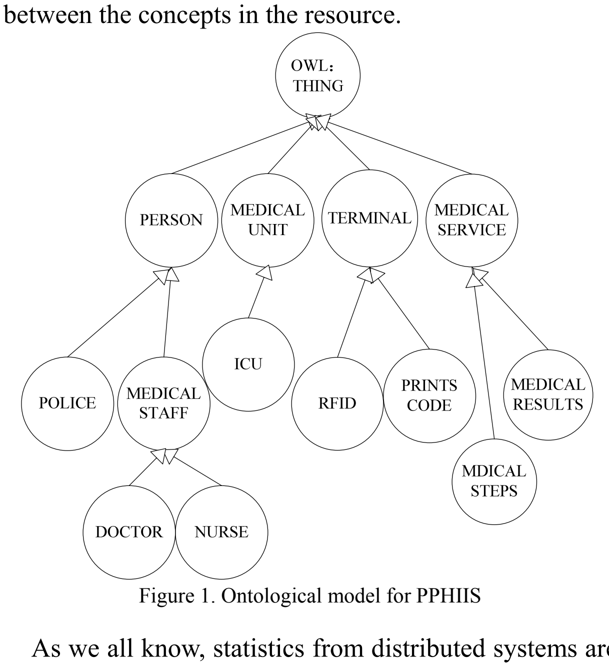

Figure 1. Ontological model for PPHIIS

As we all know, statistics from distributed systems are heterogeneous, in the existing system, sometimes police cannot provide the medical staff with complete information of the historical data, as a result of language barriers or unconsciousness, for example. We here brought multi-agent in PPHIIS, which is adopted to provide users with inquiry services to settle the problem that the information resource could not be shared.

In the era of service explosion, how to search service efficiently and exactly has been a huge headache and brought along its share of frustrations for developers. W P. Pan focused on the building of a tag ontology to enhance the semantic searching of services, and final to tackle this problem. By this method, we improved the efficiency of searching the corresponding service[21]. The framework of PPHIIS is based on MDA (Model Driver Architecture), and is designed in view of the framework needs and the advantage of characteristics of the organization agent. To build the architecture of PPHIIS, we firstly present a framework structure based on multi-agent, which makes PPHIIS more available and robust to the dynamic & distributed environment, as is shown in Figure 2. Wherein, the Integration Gateway of Web Service provides agents and Web Service (WS) with more interoperability: the police interface agent could be updated through RFID; medical staff could also organize the agents through a shared database to extract health information of the police, which are finally stored in a ".xml" file.

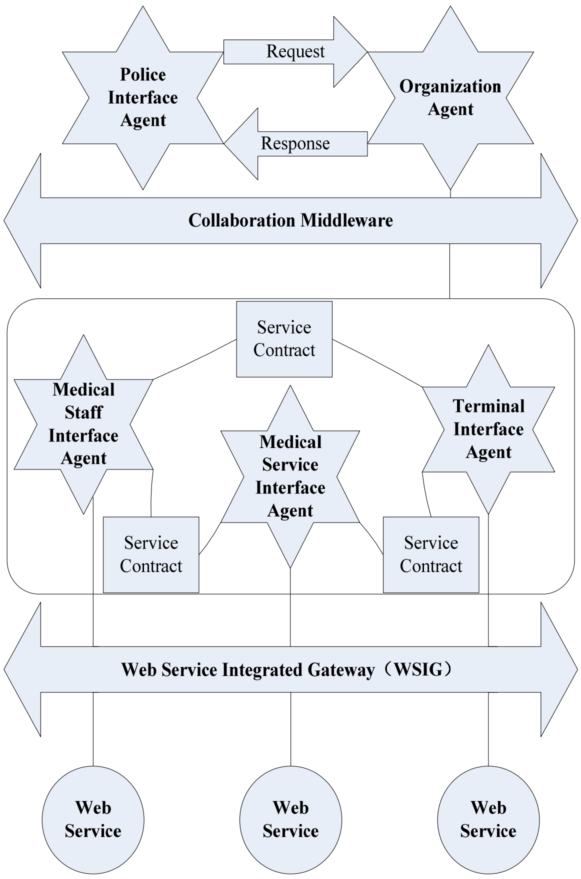

Figure 2. The agent-based framework of PPHIIS

III. Design and Implementation

A. Functions

PPHIIS provided users with five functions as follows:

(1) Information release and acquirement: there are two ways to acquire the initial information.

(2) Users send personal information to the server-side directly through HTML in the customer-side, then the received application is converted into a RDF file;

(3) Send a URL link to the personal information resources effectively, and get access to information resources of the system, as well as to generate a copy stored in the server.

(4) Maintenance of PPHIIS mainly includes adding, modifying, removing, canceling some information and other functions. Users could directly modify the information, namely the RDF file, stored in the client, then sends a message to notify the execution of the service and timely update the server.

(5) Information query and sharing. PPHIIS also provides users with information query and shared services.

B. Structure Design

System structure design

PPHIIS adopts three layer architectures based on B/S mode, in which the intermediary stands on these jobs such as constraints, data access, legitimacy inspection, etc. Among transaction processing, the middle layer of Jena is evolved from HP LABS by the open source toolkit of RDF processing. There are two types of data files stored in the layer: personal information file and the resource file of ontology.

C. Module and Realization

Function module and realization

Based on the requirement of the system, meanwhile, considering the needs of semantic Web, several function modules work together to support information publishing, maintenance and query operations in the process of design & implementation. Some of the modules are provided by the toolkit of Jena.

RDF file generator is used to generate RDF file. There are mainly two ways:

(1) receive data from the servlets and transmit the file into RDF file;

(2) according to the submitted URL, users could read the information, verify its correctness and generate the RDF file.

RDF Parser is used in the parsing of RDF file, and RDF Query Engine is used to query RDF graphs. The selection is RDQL query engine, it supports RDF Polling SQL language, which is similar to SQL query language. We used it to get access to files or data stored in a large database. Inference Engine is used to perform logic function. It will reason the algorithm with RDF graphs together, mainly through ontology & axioms, which can be concluded that RDF graphs don't include assertions. Servlets and JSP (Java Server Pages) are not an independent functional module, but they play a very important role in the system, such as extracting data from HTML.

D. Application

In order to solve the problem of semantic heterogeneity and message parsing, W D. Zhao designed and achieved an ontology library, in the ontology library which can achieve knowledge sharing and reusing, many terminologies and concepts relating to the multi-agent system were used to describe the integration of middle ware[22]. Ontologies are data schemas, providing a controlled vocabulary of concepts, each with an explicitly defined semantics. By defining shared and common domain theories, ontologies help people to communicate concisely, supporting the exchange of semantics. Our notion of application aims at the integration of a multitude of disciplines in order to facilitate the construction of ontologies in PPHIIS. Here we will take the interface agent of police and the organizational agent as an example to describe the entire process about how police inquiry the health information in PPHIIS, as is shown in Figure 3. First we meet the needs of police: submitting, querying and updating the health information; meanwhile, we also meet the needs for the medical staff: querying the medical information (through the organization Agent), updating the medical information (through the organization Agent), starting the organization agent to save the heterogeneous data, followed by parsing the XML file, making data format unified, and finally feedback the query result to the interface agent of police, in this way, police could acquire the results from the interface agent of police.

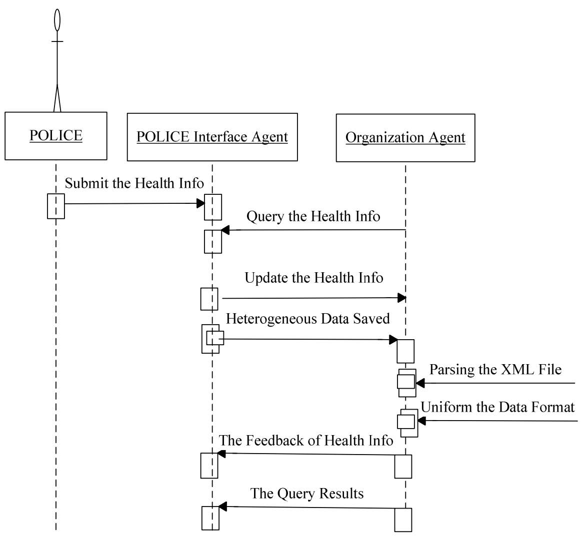

Figure 3. The sequential diagram of police in PPHIIS

IV. Definition and Discussions

The separation of concept reference and concept denotation, which may be easily expressed in RDF, allows to provide domain-specific ontologies without incurring an instantaneous conflict when merging ontologies. Here OWL is used to describe the medical information in PPHIIS mainly in the following two steps: First, In order to fully display the medical information, we define a formatting template T:

$\cdot T = <S, O^S, R, C, E>$

O^S is the set of concept properties, where S represents the individual concept property, for example, if set Oi is a sub-concept attributes of set O, then we can use O^S (Oi) to indicate the description, set S is defined as follows:

$\cdot O^S = O^{S1} \cup O^{S2} \cup O^{S3} \cup O^{S4}$

$\cdot O^{S1} = \{CO \mid CO \in CODE\}$

$\cdot O^{S2} = \{CA \mid CA \in CATEGORY\}$

$\cdot O^{S3} = \{DA \mid DA \in DATETIME\}$

$\cdot O^{S4} = \{NA \mid NA \in NAME\}$

O^{S1} indicates the code of correspondent fingerprint of each police participating in the examination; O^{S2} indicates the classification of the health department; O^{S3} indicates the time when police were examined; O^{S4} indicates the correspondent name of each police who participated in the examination.

Set R is associated with set C; r $<Cs_1, Cs_2> \in R$ represents the relationship between Cs_1 and Cs_2, where $Cs_1, Cs_2 \in C$ $(s_1, s_2 = 1)$, $Cs_1, Cs_2 \in C$. This group's semantic model is as follows:

$\cdot R = R_1 \cup R_2 \cup R_3$

$\cdot R_1 = \{IsA, IsAttachedTo\}$

$\cdot R_2 = \{RELATION1, IDENTIFY\}$

$\cdot R_3 = \{RELATION2\}$

Therein, R_1 accurately indicates the relation between police and the defined relation between the medical steps; R_2 represents the associated police and the attached fingerprints; R_3 represents the associated police and the diagnostic procedures.

Set C derives from set S, expression $<S, C>$ represents the semantic structure derived from node S, where C is the relation between any two concepts from S. For the two conceptions S1 ,S2 $\in$ S, relation $S2 \leq S1$ is true, if S1 is any instance of S2. For example, DOCTOR≤ MEDICAL STAFF. Furthermore, Set E is a collection of axioms which define constraints for concepts or the relations between them; In order to record the medical information, we define a semantic model, where set B is defined as the set of several conceptions:

$\cdot B = B_1 \cup B_2 \cup B_3 \cup B_4$

$\cdot B_1 = \{P \mid P \in POLICE\}$

$\cdot B_2 = \{F \mid F \in FRAME\}$

$\cdot B_3 = \{T \mid T \in TERMINAL\_FLAG\}$

$\cdot B_4 = \{E \mid E \in EXAMINE\_STEPS\}$

Therein, B_1 represents the medical service; B_2 represents a framework for the deployment of medical service; B_3 represents handheld devices which could identify the fingerprint code; B_4 represents the diagnostic procedures.

An ontology differs from an XML schema in that it is a knowledge representation, not a message format. Local ontology is a view at a conceptual level in the data sources, which will be mapped corresponding to the relevant concepts of global ontology, the result of mapping is the rules in a ontological library. All the local concepts and attributes are mapped into global concepts and attributes. In PPHIIS, it not only makes a clear description of the semantics of the medical information, but also makes the data source and the global body separated. Meanwhile, it greatly reduced the coupling. In the medical service of PPHIIS, in order to perform each execution, we also proposed an ontology model, where health care as a tree root is the principal, any simple action requires a relevant combination of some specific disease of patients to take further medical diagnosis. In addition, all the procedure of each execution is translated to obtain the results for each diagnosis, finally the results were saved in a ".xml" document, the relations are illustrated in Figure 4.

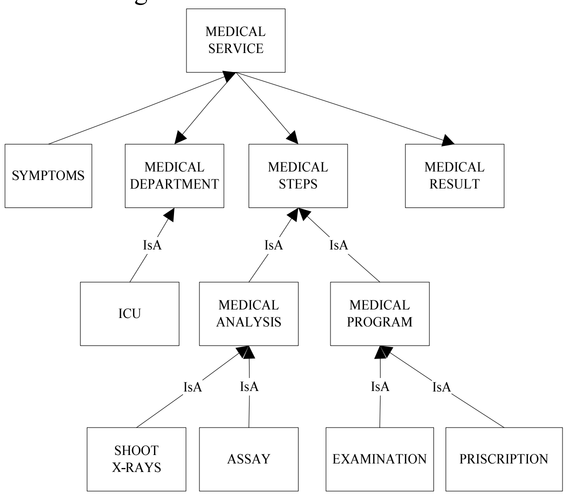

Figure 4. Node Medical Service and his relations

In order to query all the medical information of each police, here we also created a semantic model which contained all the conceptions and their relations associated with the entity of police in PPHIIS, where the police conception is an ancestor node, represented in Figure 5;

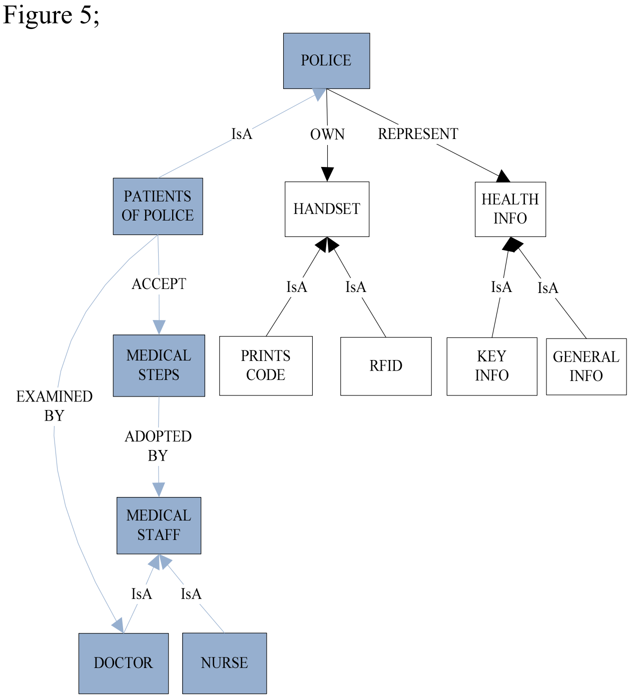

Figure 5. Node Police and his relations

After finishing the preliminary steps for creating an ontology model, we again achieved a hierarchical structure for the conceptions involved in updating the patients' medical information. In order to identify the patient, the fingerprint code was applied in PPHIIS, wherein, each code was corresponding to each police, and all the fingerprint information is stored in RFID, shown in Figure 6.

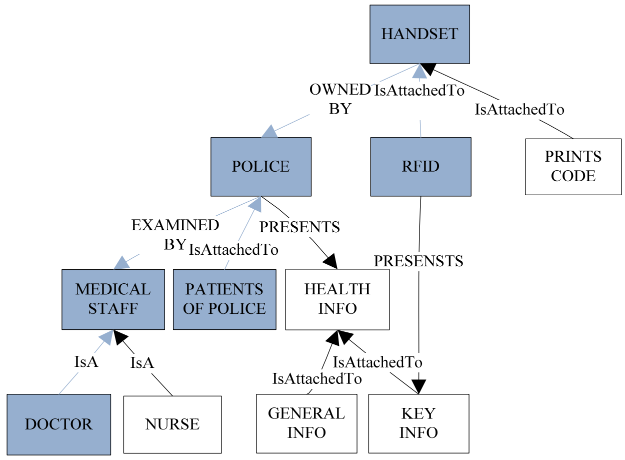

Figure 6. Node Handset and his relations

In PPHIIS, in order to make each model compatible with each other, we extended all the conceptions as follows: police, handset (handheld terminals), medical staff and medical steps. The main significance of the proposed ontology is that the complexity between each model and its restored historic medical information is greatly reduced. There are of interests for medical staff in several situations of emergency related to our proposed ontology structure with the main nodes included. The extended ontology model with OWL format was designed in an illustrative example to represent the general nodes of distribution in PPHIIS, a rule-based application with intelligent reasoning is implemented by Jena to validate the effectiveness. To provide the semantic agreement among multi-agents, the formal communication between police and the hospital in PPHIIS is represented.

To make a conclusion, database relations to OWL based ontology for the local sources were mapped, which not only minimized the errors and effort involved in ontology building but also allowed adding additional semantics in the system. Its distinguished feature was to create ontology from relations in the absence of necessary metadata, compared with the situation where a quite complex global ontology was applied in PPHIIS, a more simplified set of conceptions emerged with the mapping between global ontology and local ontology, meanwhile, a level of abstraction at which we envisage integrated systems carrying out cooperative work by inter-operating globally across networks connecting police, hospitals and terminals was offered by the multi-agent view, users relished the extendable model for its high-efficiency, low-expenditure and, the system enabled both police and medical staff to extract medical information in detail more efficiently, as was shown in Figure 7.

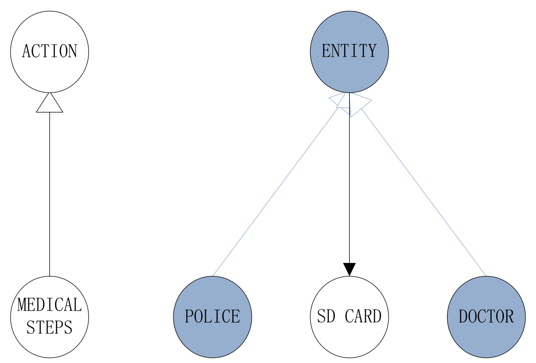

Figure 7. The overall model

V. CONCLUSION

In PPHIIS, multi-Agent systems provide an intelligent middleware for information exchange between distributed systems, to achieve all the medical information in the system, we proposed a framework in which the ontologies were used to process the semantic integration of the information. Therefore, it can be indicated that the combination of the two technologies are in need to make the integrated system more efficient and robust, which not only improve the efficiency of the information sharing, but also provide a new base for the future development of data integration system. In this way, for the same interface and the unified target, new team members can get up to speed quickly on the work done by others, which is very important when documentation is not enough or gone. PPHIIS processes data very fast, government can take advantage of a load-balanced architecture that can quickly transform and move data between different platforms and distributed systems. PPHIIS also supports zero data movement by using SQL pass-through into persuasive database responsorial, for example, Oracle, MySQL, SQL Server, DB2 and Hadoop. To build the mapping relationship between global ontology and local ontology, we need to adopt the automatic matching algorithm, which we will make profound research in the next step for the homogeneousness of the heterogeneous data in PPHIIS.

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