An Adaptive Architecture for Healthcare Systems
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Abstract—In this paper we present an adaptive architecture for designing an effective healthcare system. A development of this architecture has adopted the Requirement-Driven Adaptive Architecture (RDAA) and incorporated the service-oriented features. It has been applied in and validated by the project of Interoperable Regional Healthcare Service for the Chinese PLA General Hospital.

Index Terms—Requirement analysis, healthcare systems, SOA, RDAA

I. INTRODUCTION
Healthcare systems like other business information systems that they involve business collaborations within and across organisational boundaries. To design such systems, it requires a holistic view over the issues of 1) who requires healthcare services; 2) quality of the healthcare services; 3) tailortablity of the healthcare services to meet personalised needs; 4) architectural representation of the healthcare services; and 5) discovery and configuration of the healthcare services for a specific request. Web Services have been widely used for developing information systems with such complex features. With this approach, the functionality provided by business applications are encapsulated within software components and technically supported by SOAP, WSDL, and UDDI. However, Web Services lack of capability for modeling a dynamic aspect of the service. Many emerging languages, e.g. Business Process Modeling Language (BPML), Business Process Execution Language (BPEL), and Business Process Modeling Notation (BPMN) have been developed to serve this purpose. To integrate these capabilities from Web Services and business process modeling, service-oriented architecture (SOA) provides methods for information systems development and integration where the technical functions should be structured around business processes and package these as interoperable services.

SOA and Web Services are not fully capable of analysing and modeling a complex healthcare system which involves multiple stakeholders with multiple concerns. These stakeholders demand personalised services to meet their needs. To address this problem, we present a new adaptive architecture which will be discussed from its underpinning theory of RDAA in Section 2; the methodological functions of RDAA which can be adopted in this development in Section 3; the description of the adaptive architecture with its application in Section 4; and the conclusion is drawn in Section 5 where some future work are proposed.

II. RDAA OVERVIEW
RDAA presented in Figure 1 comprises five layers, five stanchion, technology and physical infrastructure [1][2].

![Figure 1. Requirement-Driven Adaptive Architecture](image)

User requirement layer analyzes and identifies user requirement, it also gives standardization and pattern recognition for user requirement. Business service layer is for service classification and standardization. Found and consummate service pattern library. Business process, function and data layers realize process start, function execution, resource controlling and managing of business service in turn, URDL is used for user’s requirement, Business Service Description Language (BSDL) is used for business service, and Business Process Execution Language (BPEL) is used for business process. These three languages are advanced protocols of RDAA. In RDAA, function and data layer use SOA based on web service [3].

Pattern, case, ontology and specification library of requirement, services and business process are foundation of RDAA. Layer mapping and self-adapting mechanism are basic operational mechanism of RDAA. Consequence based on specification and cases together with Agent technology make RDAA adapt changes of requirement and environment, also make it with ability of self-consummate and self-evolution. Semantic consistency during layer mapping, consequence and matching are realized by searching ontology library. Processing
specification and knowledge, organizing specification and knowledge, society specification and knowledge, these are three features of RDAA. When society or organizations changing, RDAA can track the change of environments. This makes RDAA with more agility and adaptation. Information sharing and security make RDAA run safely. Meanwhile, it makes RDAA support information sharing and mutual manipulation.

III. LAYER PATTERN MATCHING AND LANGUAGE STUDY

We use the formal or semi-formal tools such as Petri nets, UML together with investigation and systems analysis to establish layer modes, especially user requirement pattern (URP), business service pattern (BSP) and business process pattern (BPP).

A. Layer modular design and matching

1) User’s requirement layer

The design and matching of URP. This makes classification and standardization for user’s requirement which appear more frequently, in the form of various user’ requirement patterns (URPs). URDL which can be recognized by system to describe and define user’s requirement is adopted to construct URP. A user’s requirement is always realized by one or many services, some service patterns are organized effectually to satisfy user’s requirement. The usage of URP and transaction engine can satisfy changes of user’s requirement compared to basic requirement. For example changes in engine can satisfy changes of user’s requirement. The usage of URP and transaction engine can satisfy changes of user’s requirement.

The mechanism of URP matching is as follows: searching engine search and matching URP in URPs library, if succeed, calling certain service; if failed, system will form a new URP, calling lower layer for a new service pattern. Whenever the result according with some specification, it will be added in to system as a new URP [4][5].

Requirement/Service mapping and calling. Mapping mechanism can transfer URP to service pattern. Mapping of two layers is stored in requirement library. The URP will be satisfied by offering standard service description. Under the support of knowledge library, Requirement/Service mapping use user’s requirement agent to realize intellectualized matching, and then call for matched service pattern [6].

2) Business service layer (BSL)

The design and matching of business service patterns (BSPs). Business service layer is made up of business service engine, BSPs library, case library and specification library. In BSL, every service pattern corresponds with one or several business process pattern which is composed dynamically with certain business relation. Business service description language (BSDL) is adopted to describe it. Service pattern can orient user or self-adaptive service provided by URPs, which can’t be realized by current function model nor business process pattern. Service requirement is beyond single business process and service usually need support by some various kinds of business process.

3) Business Process layer (BPL)

The design and matching of BPP. BPP is used for classification and specification of business process. BPP is described by business process execution language (BPEL). A BPP may be made up by many independence function subassembly, or may contain other BPPs. They are managed and called by logic of service pattern which provide service to user. BPP is an advanced service pattern, and under the current condition of commercial activity, business processes usually need many functions work together. BPP of web service which is based on XML, SOAP, UDDL is popular now [7]. In RDAA, we use BMPI, expending BPML and BPEL in order to suit the description and execution of business process.

4) Function layer (FL)

The design of Function Pattern (FP) and its mechanism. FP is used for classification and specification of application service with certain function model. A BPP is made up of many function models. A function model is made up of some data manipulation models. Function model is a popular service pattern, executing business logic by high level language and operating data by data manipulation language, to provide user with functional service. The feature of function model is the fixed interface of man-machine interaction, so the function is predesigned according to program. In FL, management is embedded in execution process which mainly relates to technology. For example several of high level language, software architecture, design and develop method etc. function model is middle layer between user’s logical operation and physical information operation [8]. In RDAA, we define function model using web service technology which makes RDAA more flexibility and expansibility.

5) Data layer (DL)

Difference from other models, data model realizes transferring from information service to physical
information operation, which is the fundamental mode of the whole self-adaptive information service. Data model and its mapping pay more attention to technical realization of physical information operation, using lower level language which can be recognized by hardware system. Typical instance of data layer is database managing system. Mapping between function model and data model use normal data driven mode like JDBC, ODBC etc.

B. Design language in RDAA

1) URDL, based on XML and XPath, describes a series of formula of grammar and semantic, and it is actually operation protocols of application layer. URDL is specification language used for description of user’s requirement layer. A URDL must represent user’s requirements clearly, including functional demand and non-functional demand; define questions, solution method, restriction, condition and environment; express logical relationship between user’s requirement and business service; and execute mappings.

2) BSDL represents business processes where stakeholders are responsible to conduct communications by following the business norm. BSDL also realizes control between manage layer and application layer by hierarchical control.

C. The adaptive mapping mechanism

The searching and mapping mechanism between neighboring layers assisted by norm based reasoning, case based reasoning and necessary human coordination are the operation mechanism of our system.

The basic information unit in each layer is pattern (ref Figure 1). A user requirements pattern is the collection of characters of a whole requirement. A business service pattern is the collection of characters of a whole service in certain business domain and other layers are similar. There are one-to-many relationships from upper layer to lower layer. That is to say, a URP matches one or several BSPs and a BSP matches one or several BPPs.

The granular size of the patterns in this framework become larger and larger form bottom level to top level. The granularity of patterns and the mapping mechanism are the basis of system’s adaptability to changing requirement and environment, since various permutation and combination of small-sized elements from lower layer can satisfy the changes of large-sized elements from upper layer[9].

IV. A HEALTHCARE SYSTEMS ARCHITECTURE

A healthcare information system is normally complex and dynamic, because it involves various stakeholders, such as patients, physicians, hospitals, government and the third-party institutions, with different interests and concerns [10]. Their requirements need to be modeled to possess reusability, expansibility, adaptive and self-evolving ability. Therefore, RDAA has been adapted to create a healthcare systems architecture (see Figure 3) which can guide an analysis of users’ requirements and build a IT-enabled healthcare system.

Figure 3. The adaptive architecture for healthcare systems

There are five major components, i.e. requirements layer, service layer, process layer, function layer and data layer, and the mapping mechanisms which facilitate communications between the layers based on the patterns in their corresponding layers.

The RDAA’s technique of URDM can be used to articulate and model the user’s requirements for a focal stakeholder, e.g. patients in the requirement layer. A clear understand of each stakeholder’s needs will form the basis (i.e. URP) for a business service pattern in the service layer. Service layer interacts with requirement layer and provides services in certain domains to satisfy user’s requirement pattern. Each domain, for example medical domain, has its particular BSP. A BSP comprises the requirements described by URPs and the behavioural process. The process enables to deliver the right service required by the right users. To generically pattern processes for services, the process layer pre-define some common processes which are likely to be conducted by hospitals, health bureaus, healthcare communities, and etc. Each BSP can be supported by the BPPs.

A BPP delivers the service by executing functions which manipulate data from data sources. The functions are defined in the form of web services which can be invoked by the BPP to provide the capabilities of the BSP to meet the user’s needs in the URP. The data layer complies the medical data exchange standard HL7 (Health Level Seven) and DICOM (Digital Imaging and Communication in Medicine) which are applied for distributed data sources.

The adaptive architecture for healthcare systems enables the modification of norms and ontological knowledge according to the changes of society, organization and environment. The information sharing mechanism supports interoperation, data sharing, and security control.

The adaptive architecture for healthcare systems was applied in the demonstration project of Interoperable Regional Healthcare Service for the Chinese PLA General Hospital. This project is one of the National Key Technology R&D Programs which investigates and
demonstrates the establishment of regional healthcare cooperation, community health construction and regional health data center. The outcome of this work provides the direction of theory, methodology, and standard for designing an effective healthcare system.

V. CONCLUSION

RDAA decompose and organize information services into five levels, which help to realize specification, components and easy integration of business logic. By decomposing top-down and organizing for requirement bottom-up, the commonness and individuality of business requirement in macrocosm and microcosmic are both unified. The problems of requirement such as variation, instability and nonstandard represented are resolved. In this paper, we present RDAA, discuss the layer pattern matching and language study, function call between layers and operational mechanism in RDAA. RDAA is not only considering the various management organizations but also using hierarchy and layer mapping, together with intelligence information processing, semantic web method and technology, which provide system with feature of self-adaptive, self-improvement and self-development, being smart to meet user’s requirement. In technology, RDAA is based on SOA but is advanced than SOA, and provide information systems with social attributes, highlighting characteristics of people-centered.

Our future work includes semi-automatically constructing the ontological knowledge for the system. The analyzing and modeling of Business Service Pattern in service layer is also under investigation.

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