

# Clinical Decision Support Based on FHIR Data Exchange Standard

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**Abstract.** With the improvement of the level of medical information, the major hospitals have the appropriate medical information system (Hospital Information System, HIS) to manage clinical medical data. However, because of the difference of HIS, the structure of clinical medical data is also different, which seriously affects the transmission, compatibility and use of clinical data, that making the data incomplete or can't be effectively used. In this paper, we use the Fast Healthcare Interoperability Resources (FHIR) standard to standardize the exchange of clinical medical data, and build a data sharing platform with multi agent platform, so that the clinical medical data can be integrated by Agent for clinical decisions making.

## 1. Introduction

In real life, the patient's information is scattered in different areas of the hospital, the medical institutions use the database or data format is not the same. In order to make full use of the information for clinical decision making, it is necessary to realize the sharing of patient information under the uniform standards.

For the standard of clinical medical information, the internationally recognized authoritative organization Health Level Seven (HL7) [1] have made great efforts in the formulation of standards. They have issued Clinical Document Architecture (CDA) [2] as the standard of clinical medial standard, which has been widely adopted. But, CDA still has a lot of limitations, so the HL7 organization combines the best features of HL7 V2, V3 and CDA, while using the latest web standard developed FHIR. FHIR will be the next alternate version.

Based on the FHIR standard, the patient information saved in the database is transformed into clinical data, and then exchanged and shared among different HIS. So that, we design a data sharing decision platform.

## 2. Background

Multi Agent System has very good support for branch decision making, with this platform we can easily achieve the integration of distributed data collection. And, the message type between Agents can be unified specification for FHIR. With complete data, Agents can make decision by rule knowledge repositories.

### 2.1 Fast Healthcare Interoperability Resources (FHIR)

The Fast Healthcare Interoperability Resources FHIR [3] is a set of international clinical medical standard issued by HL7 for specifying clinical data structure and semantics. FHIR aims to simplify implementation without sacrificing information integrity. It leverages existing logical and theoretical models to provide a consistent, easy to implement, and rigorous mechanism for exchanging data between healthcare applications. FHIR defines a set of "Resources" that represent granular clinical concepts. The resources can be managed in isolation, or aggregated into complex documents. Based on this, conventional data in database can be transformed into clinical medial data.

### 2.2 Agent Based Decision Support Platform

Agent [4] is a concept mentioned in the Multi-Agent system. From the Multi-Agent system of distributed artificial intelligence, the basic idea is to encapsulate various problems to a solution of the autonomy of the Agent, through the interaction between the Agent coordination, cooperation and

negotiation together to complete the task. The characteristics of the Multi-Agent system [5] are similar to those of the clinical decision making in real life, and can be used to build a data sharing platform. With the platform, the clinical medical data maintained by Agents can be shared with each other and integrated to better use. With the complete data, the decision of Agents can be more scientific and reliable.

### 2.3 Expression of Clinical Guidelines Based on Rule Knowledge

In expert system [6], machine imitates the reasoning way of human beings, uses the heuristic method to carry on the inference, and uses the terminology which the human can understand and explain its reasoning conclusion, the way how to infer is defined as Rule. The rules are placed in a central database or elsewhere, and can be dynamically managed and modified at runtime. In computer science, rule-based systems as a type of expert of expert system usually format and store information into special data formats. In this paper, we conclude the clinical decision making scheme into XML format as decision rule. XML is a makeup language that defines a set of rules for encoding documents in a format that is both human-readable and machine-readable. Through the corresponding rule engine to maintain and interpret the rules, and use rule knowledge repositories as support to guide and assist doctors in clinical decision making.

## 3. Design and Framework

In order to realize the integration and application of distributed clinical medical information, we design a Multi-Agent Decision-Making Platform, which can reduce the waste of medical resources and save the cost of medical decision-making [7].

In this platform, the database of each independent medical platform is used as the original data source. As the standard of message passing in Multi Agent System, FHIR avoid the conflict and confusion of data from different medical platforms. As the standard of Agent's behaviour, rule determines the behaviour of Agent. Agent integrates received FHIR messages with the identified data in database to generate complete Patient Resource as the input of Rule Engine. The Rule Engine compare Patient Resource with Rule Repertories to drive Agent's next step. Figure 1 shows the task process of Agent using FHIR. Agent invokes FHIR Message Wrapper to encapsulate into Patient Resource, then call Rule Engine to get the data from Patient Resource according <attribute> node in rule document, using "operator" property and "key" property as criterion of Rule analysis. According to the result of Rule analysis, the Agent make a decision or choice the next data receiving Agent.

### 3.1 The Structure of FHIR

FHIR uses standardized data formats and elements, collectively called "Resources" [8]. A Resource is the smallest possible unit of transaction in FHIR, with a known identity providing meaningful data. These Resources can easily be assembled together and are suitable for use in a wide variety of medical platforms to address real-life clinical and management issues. FHIR Resources covers a variety of concepts related to clinical management, such as patient, provider, organization and equipment, as well as the clinical concept of all kinds, including drugs, diagnosis, nursing plan and financial problems etc. Most resources are inherited from Domain Resources, including Human Narrative, Contained Resources, Extensions, as an abstract resource does not directly generate. In Figure1 the Agent Decision Platform use the "Patient Resource" to share clinical medical data of patient and instantiate "Patient" to generate personalized "Patient Resource".

### 3.2 The Structure of Rule

The Rule is a set of template based diagnosis scheme expressed in clinical guidelines, which is stored in the rule repertories in the form of XML [9]. The rule execution module consists of two functions: rule analysis and electronic medical record. After obtaining the information of electronic medical records, the rule engine is analyzed according to the rules stored in the rule repertories. The rules are encapsulated together by <productionRule>, the head is used as the identifier and the scope of the rules, and the main body is the content of the <decisionTree> package. There are multiple <candidate> in <decisionTree> as the choice of decision making. <attribute> is a patient's data which

can be found in Patient Resource, if it matches, the corresponding <argument> is a valid parameter. Finally, the “weight” of the valid parameter determines whether to select the current <candidate>.

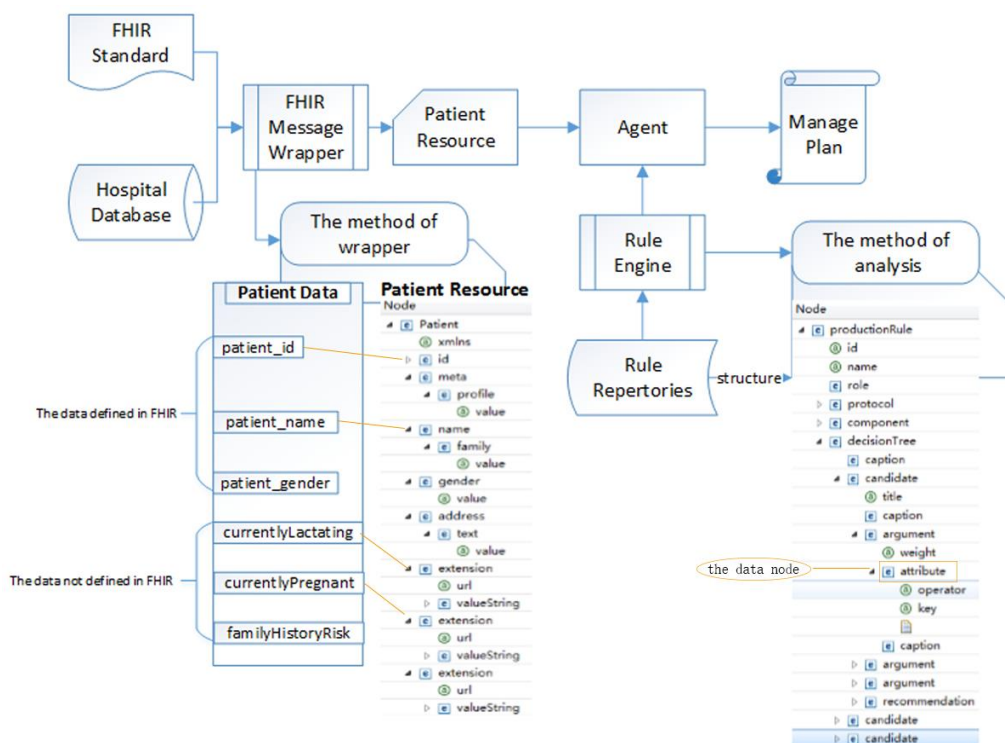


Figure 1 The FHIR in Agent Decision Platform.

#### 4. Case Study

We take the PROforma's Triple Assessment [10] of breast cancer as an example. Triple Assessment is an interactive decision support tool to support the management of new patients in a triple assessment clinic. The model includes four key decisions made for every patient: a genetic risk assessment; which radiological investigations to perform; which pathological investigations to perform and, finally, whether to refer, discharge or follow up the patient.

To this case, we defined Surgeon Agent, Radiologist Agent, and Pathologist Agent to simulate the operation of Triple Assessment of breast cancer (as Figure 2 shown). The Triple Assessment shows that a breast cancer patient's diagnosis involves at least three doctor (surgeon, radiologist and pathologist). For this, Surgeon Agent, Radiologist Agent and Pathologist Agent represent this three doctors. A manage plan for the breast cancer patient may be made by the three Agents.

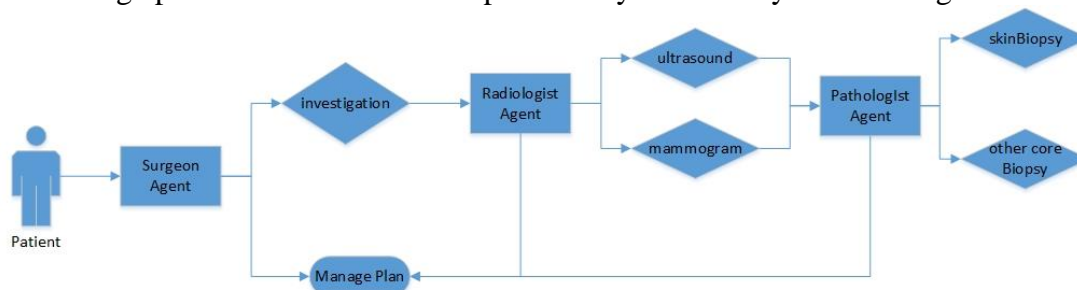


Figure 2 The Workflow of Breast Cancer Decision.

- 1) Patient with suspicious breast cancer first receive treatment by the Surgeon Agent. If the patient can't be diagnosed after the operation of the Surgeon Agent, the patient data will be sent to the Radiologist Agent. If the Surgeon Agent can solve this problem, a Manage Plan will be given by Surgeon Agent.

- 2) Radiologist Agent receive Patient Resource from Surgeon Agent, then decides to take Ultrasound or Mammogram method, according the result to send Patient Resource to Pathologist Agent or make a Manage Plan with Surgeon Agent.
- 3) Pathologist Agent receive Patient Resource from Radiologist Agent and choice which Biopsy method. Finally, Pathologist Agent together with Radiologist Agent and Surgeon Agent to make a Manage Plan.

#### 4.1 Patient Data and FHIR Resource Conversion

In order for data to be transmitted, we need to convert the patient data in the database to XML (Patient Resource). In order for data to be used, we need to convert the Patient Resource to patient data (Patient Object).

To convert the patient's data to Resource, we use JDBC to read data in the database then encode them into Patient Resource. As shown in Figure3, the left is the patient data structure in database, the right is the encode method.

名	类型	长度	
patient_id	varchar	20	//将数据库中对象转为PatientResource
patient_name	varchar	255	<b>public void Patient2Resource(String patient_id) throws Exception{</b>
patient_gender	varchar	255	//通过DAO层读取id为patient_id的Patient的信息
patient_age	int	11	PatientDao patientDao = new PatientDao();
patient_address	varchar	255	MyPatient myPatient= patientDao.findPatientById(patient_id);
patient_currentlyLactating	varchar	255	//生成FHIR的xml消息
patient_currentlyPregnant	varchar	255	FhirContext ctx3 = FhirContext.forDstu3();
patient_currentlySmoker	varchar	255	File file = new File("patient_"+patient_id+".xml");
patient_familyHistoryRisk	varchar	255	FileOutputStream stream = new FileOutputStream(file);
patient_hasPreviousBreastCancer	varchar	255	XMLWriter writer = new XMLWriter(stream, "UTF-8");
patient_latestExamination_lump	varchar	255	ctx3.newXmlParser().setPrettyPrint(true)
patient_latestExamination_nippleDischarge	varchar	255	.encodeResourceToWriter(myPatient, writer);
patient_latestExamination_nippleDischarge_varchar	varchar	255	}
atestExamination_nippleDischarge_volume	varchar	255	

The structure of patient data

the code to encode patient into patient resource

Figure 3 Method for Encoding Patient Data.

To convert the Patient Resource to Patient Object, we get the xml file based on the patient's only ID. Then, we use FHIR's Util to decode this Patient Resource into personalized Patient. As shown in Figure4, the upper half is the decode method, the lower half is the data of patient. After this, with the patient data in local database, the complete data for a patient can be obtained.

The code to decode patient resource into patient data

```
public MyPatient Resource2Patient(String patient_id) throws Exception{
    MyPatient mypatient = new MyPatient();
    FhirContext ctx = FhirContext.forDstu3();
    IParser parser = ctx.newXmlParser();
    String patientRe = FileUtil.readFile("patient_"+patient_id+".xml");
    mypatient = parser.parseResource(MyPatient.class, patientRe);
    return mypatient;
}
```

The json style of patient data

```
{
  "resourceType": "Patient",
  "id": "420111197504162987",
  "meta": {
    "profile": [
      "http://example.com/StructureDefinition/mypatient"
    ]
  },
  "extension": [
    {
      "url": "http://example.com/dontuse#patient_currentlyLactating",
      "valueString": "no"
    },
    {
      "url": "http://example.com/dontuse#patient_currentlyPregnant",
      "valueString": "no"
    },
    {
      "url": "http://example.com/dontuse#patient_currentlySmoker",
      "valueString": "no"
    },
    {
      "url": "http://example.com/dontuse#patient_familyHistoryRisk",
      "valueString": "elevated"
    },
    {
      "url": "http://example.com/dontuse#patient_hasPreviousBreastCancer",
      "valueString": "yes"
    }
  ]
}
```

Figure 4 Method for Decoding Patient Resource.



## 4.2 Patient Resource of Breast Cancer Patient

We take the data and attribute defined in Triple Assessment as a source of research data. In Triple Assessment, PROforma [11] defined the detail data a breast cancer patient need to be check and the meaning of these data. As these data to a support, decision making of Agent can be scientific and reliable.

In order to apply these data to Multi-Agent Decision Platform, we encapsulate it into a format data suitable for sharing and exchanging in the platform. In consideration of the original Patient Resource of FHIR doesn't include the above data, we use the <extension> given by FHIR to define the data we want. Each "url" of <extension> is the link of data description.

The left side of Figure3 show a customized Patient (MyPatient) which inherited from FHIR's Patient. The personalized MyPatient Resource has all the data Radiologist Agent wants to get. The right side of Figure5 show the MyPatient Resource which is generated from MyPatient. Compared with FHIR's native Patient Resource, MyPatient Resource use <extension> to involve the data not defined by FHIR.



MyPatient Resource

the definition of MyPatient

Figure 5 The Patient Resource.

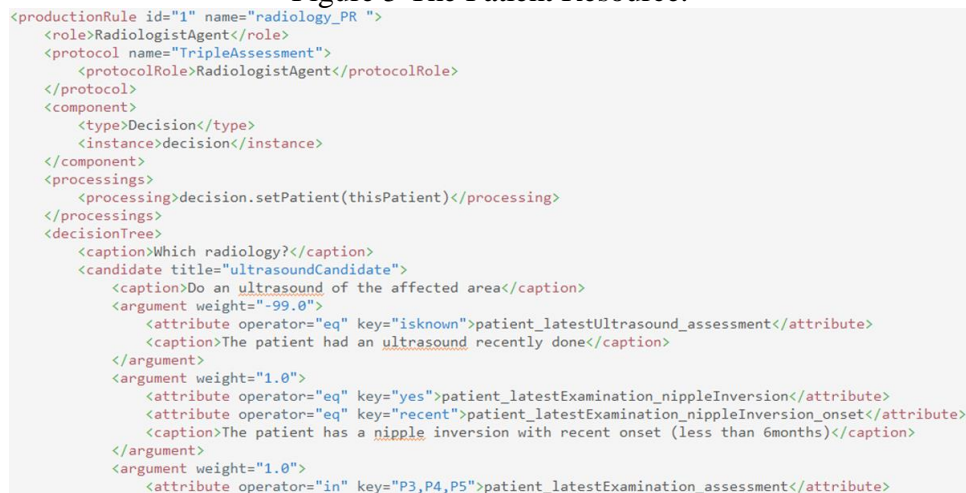


Figure 6 The Decision Rule of Radiologist Agent.

## 4.3 Application of Radiologist Agent to Patient Resource

When the data of breast cancer patients were sent to Radiologist Agent by Surgeon Agent, Radiologist Agent got the data in Patient Resource and used it as the input data source of rule engine. According to the Radiology rules (radiology\_PR.xml, as shown in Figure6), Rule Engine traverses <attribute> in "radiology\_PR.xml" to obtain the corresponding <extension> in Patient Resource. In accordance with the corresponding "operate" and "key" of <attribute> and the value of <extension> in comparison to determine the valid of the current <argument> which this <attribute> belongs to. Finally,

the sum of the “weight” of valid <argument> and the “weight” range specified by the <recommendation> in “radiology\_PR.xml” determine the choice of <candidate>.

Based on the analysis result of Rule Engine, the Radiologist Agent can make a decision. As shown in Figure7, combined with the data obtained from Surgeon Agent, Radiologist Agent may do mammogram and ultrasound for the patient.

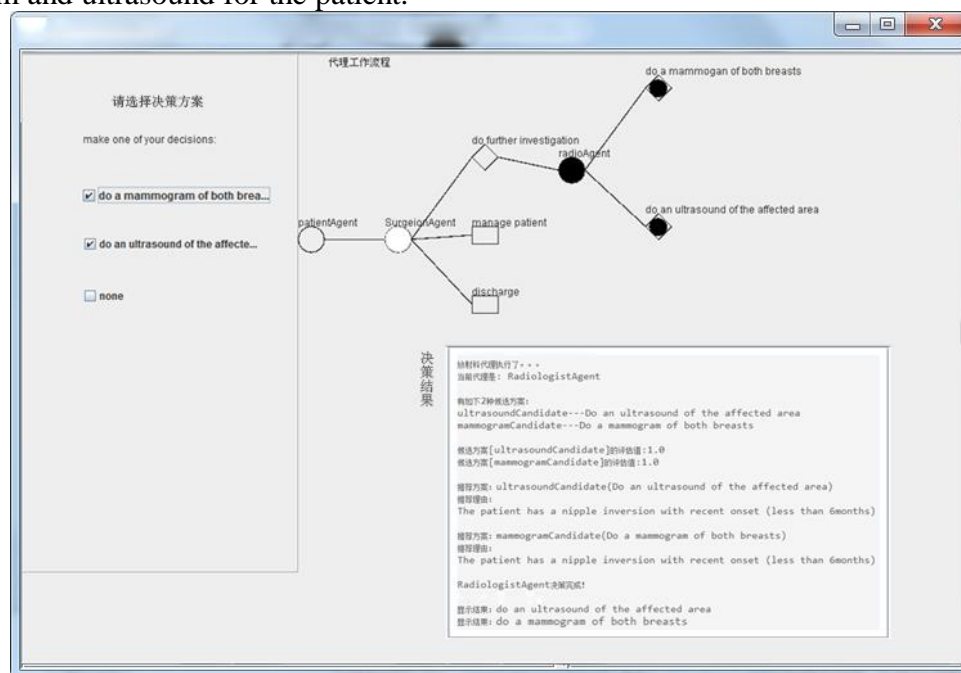


Figure 7 The Decision of Radiologist Agent.

## 5. Discussion and Conclusion

The clinical medical information plays a very important role in the construction of medical information. Nowadays, the most widely used standard of international medical information is CDA, which belongs to the standard issued by HL7, but FHIR is the next generation version. Compared to CDA, FHIR provides a number of implementation libraries and a variety of Resource type is more conducive to standardization, and its <extension> scalability stronger, in the premise of the standard can be personalized local corresponding Resource content. In addition, HL7 organizations using Web standards (XML, JSON, HTTP, Atom, OAuth, etc.) to provide a tool for the implementation of the FHIR program to support today's popular RESTful style data return. The HL7 organization is the deployment of implementation plan for the next step of FHIR. We combine FHIR with Multi-Agent System Firstly. With the Agents' interaction, coordination, cooperation and negotiation, the clinical medical data can be shared and exchanged effectively. The Rule Engine in Multi-Agent Platform can take the data to a fully used.

Once in place, the platform will bring together all data of patient and also the decision doctor. In this way, patient shouldn't carry the paper clinical record to another hospital, and doctor can also easy to get detail data of patient. These two guarantee the efficiency and reliability of clinical decision. With the exchange of clinical medical information in Multi-Agent Decision Platform, there will be a double victory on saving both life and money.

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