A Semantic Approach towards Multi-Agent Choreography in Clinical Decision Support

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Abstract. A distributed environment, medical decision-making process is becoming increasingly complex, and it usually needs more medical roles to complete the diagnosis and treatment of one complex disease. However, these medical roles typically distribute in different work environments, so the organization and coordination of these medical roles are of great importance and urgency in this situation. In this paper, a semantic approach towards multi-agent choreography mechanism is proposed to make the situation better. In this mechanism, multi-agents from distributed environments are used to simulate different medical roles, medical rules described by using the coordination meta-model based on OWL(Web Ontology Language) are designed for choreographer to organize and coordinate these agents behaviors. Taking advantage of medical rules, the choreographer could make multi-agents communicate and cooperate efficiently with each other and prompt them to do the final decision-making together.

1 Introduction

Clinical decision support systems[1](CDSS) could help clinicians to make much more accurate diagnosis, reducing medical errors and improving the quality of medical services. However, when coming the diagnosis of complex diseases, it often need multiple clinicians to work together, which brings a big challenge to CDSS.

For clinical decision-making problems, people begin to study the choreography mechanism and have made a series of achievements. PROforma[2] [3]is a computer-executeble clinical process representation language. The language has flexible decision-making and workflow that can be used to built the reliable expert system. However, in reality, patient data and messages are passed in diferent locations and the system are not very good to adapt to the distributed environment. So in recent years, the architecture based on multi-agent technology has caused the attention of researchers, agent technology provides a new way for the realization of complex decision-making system. In this context, CDSS based on rule-driven[4] is emerged. It can match different rules to accomplish the corresponding task[5][6]. Even so, a distributed environment, as the medical decision-making process be more complex, and these experts are located in their own working environments, so it needs a choreography mechanism to organize them to complete the task together efficiently and timely.

Aim at the difficult problems of decision-making in multi-agent clinical decision support systems[7], this paper presents a semantic approach towards mult-agent choreography mechanism. Choreogapher plays a role in the organization and management of medical roles, thus will be more rapidly and correctly to provide decision support and improve the adaptability of the system.

2 Approach Overview

Solving the difficult problem of medical decision-making in a distributed environment requires different sections of the participants to join them. Agents are computational entities with featurs of autonomy, concurrency, decentralisation, and pro-activeness. These are attrative characteristics for selecting agent as a carrier of each meidical participant. This approach chooses OWL (Web Ontology Language)[8] to describe the medical procedure rule. Through parsing the OWL rule, the agent is

able to organize and coordinate these medical roles, making them communicate with each other and work together. This is a choreography mechanism or not symphony, which uses a loose model to build the relationship between the agents and ensure the flexibility of them. When the coordination agent[9](choreographer) receives requests from one agent, it will build a medical team from agentgroups according to the actual requirements of the patient, and inform the selected agents to excute this task. In this paper, the agent is set as a fixed number of properties. According to the property values of the agent, choreographer could make resonable choice and then sends a series of messages to these agents to join the task queue. In a distributed environment, the medical decision-making process is mainly from the following aspects to solve.

2.1 Multi-agent coordination meta-model based on OWL

Meta-model is a metadata model based on ontology, it can more clearly express the meaning of the entity classes and the relationship between classes in the metadata. Modeling the medical process, expressing rule with a machine-readable way that can support medical decision-making process. Selection of ontology, because ontology could support the semantics, it is a prevailing way to describe the rules, moreover, it is an explanation of the applications conceptualization, which provides a shared understanding for the field. OWL is a widely used ontology language, which provides a rich modeling elements for association between the concepts. An OWL ontology includes the name of the space, ontology header files, classes, individuals, properties and so on. The ontology analysis needs JenaAPI(http://jena.apache.org/ for use case), which could read and reasoning OWL file generated by Protege(a free, open-source ontology editor and framework for building intelligent systems http://protege.stanford.edu/), including classes, individuals, and properties.

Meta-model describes the rules of the medical procedure, including the decomposition of goal, and the distribution of role. These elements and the relationships between them constitute the entire rule. This Meta-model mainly describes the four basic concepts:Goal,Plan,Role,and Agent.

2.1.1 Goal

Goal describes the result of a medical procedure to be achieved, in this metamodel, it is a top-level goal. OperationalGoal, the sub-goal, which can be performed after the decomposition of Goal. The previous OperationalGoal is depended by the next OperationalGoal.

2.1.2 Plan

Plan is a collection of tasks that an individual intends to carry out to achieve its Goal, such as Enquiry,Decision,and Action[1].

[1] Enquiry:enquirie and collect the information of patients in order to make the right decision.

[2] Decision:make decisions for the inquiries.

[3] Action:excute behavior after making decisions.

2.1.3 Role

Every OperationalGoal is accomplished by the specific medical role. Role determines the type of participants, and it can be played by agents. The relation between agents and roles is similar in the relation between interfaces and classes in the object-oriented design.

2.1.4 Agent

Agent has autonomous capabilities. As far as complex care pathways are concerned and when a multidisciplinary clinical team is involved, Multi-Agent Systems seem to be a feasible solution[1].

Every agent has a number of fixed DatatypeProperty, such as AgentName, AgentURL, AveTime, PraTime, NumOfVisit, QuaOfService, PriOfService,etc. The list of DatatypeProperties is shown in Table 1.

Table 1. the definition of DatatypeProperties for an agent.

ObjectProperty	
AveTime	The average time spent
PraTime	Time in the medical profession
NumOfVisit	The number of admissions
QuaOfService	Attitude of service
PriOfService	Service fees

2.2 coordination agent for the organization and coordination of medical procedure

After receiving the the request sent by the relevant agent, choreographer invokes the above model has been created, and parses rules, then it gets all the subgoals, organizing the corresponding roles, and selects the appropriate agents to join the decision-making. The detailed process is:The first step, choreographer finds the corresponding role based on the decomposition of the subgoal; the second step, choreographer selects the best agent from the corresponding AgentGroup in MAS(Multi-Agent System); The third step, it forms a team of all the best agents, and inform them to join the medical decision-making process.

2.2.1 AgentGroup

AgentGroup is a new concept introduced, which consists of a number of agents which are similar in function. It has the same properties of these agent but different property values. Every role has its own AgentGroup.

2.2.2 Choreographer

In a distributed medical procedure, coordination agent(choreographer) is the agent that organizes and coordinates the medical process. It clarifies the relationship among the various medical roles and organizes these medical roles, so that they could communicate with each other and work together. When an agent from the medical decision-making system can not complete the task alone and requires another agents to collaborate, it sends a request message to the choreographer. Choreographer receives the message, and invokes the model which has been created, then gets the goal,roles,properties from the model, and finds all the appropriate agents in the model. Finally, choreographer form a team to excute the task. The system framework is shown in Figure 1.

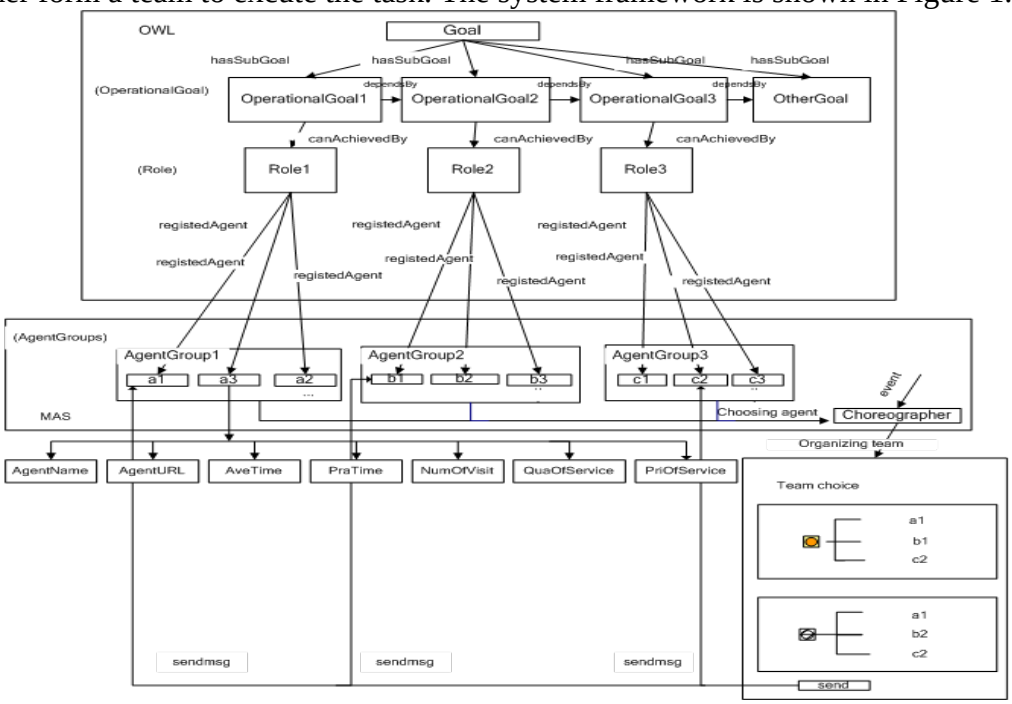

Figure 1. This figure shows the system framework, the upper part of the figure is a multi-agent coordination metamodel based on OWL, and the middle part of the figure is MAS, it includes AgentGroups and choreographer.

3 Case Study

3.1 Treatment process of Triple assessment

In this section, triple assessment of breast cancer[10][11] is choosen as the case to illustrate how the mechanism mentioned above works,beacuse the diagnosis and treatment of breast cancer is very complex, it requires medical roles from different workplaces to participate in and make joint clinical decision making. In the triple assessment of breast cancer, the medical role first needs to learn the history of the disease from patients that determines their risk of breast cancer, then it possibly be with the help of SurgeonExamination, which mainly is bilateral breast examination, and combine

RadiologyExamination, including breast X-rays (mammography camera), ultrasound. The final diagnosis will be based on BiopsyExamination. The treatment process of triple assessment could be summarized as a workflow shown in Figure 2.

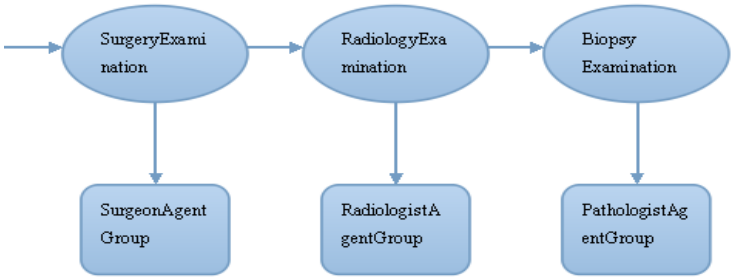

Figure 2. The treatment process of Triple assessment

3.2 Model for the treatment process of Triple assessment

According to the meta-model described in the previous section, we have built a business model for the triple assessment, this model creates a top-level goal (<Goal>) as shown in Figure 4, TripleAssessment, which contains three sub-executable goal (<OperationalGoal>): SurgeryExamination (surgery examination), RadiologyExamination (image examination), BiopsyExamination (pathology examination).

3.2.1 SurgeryExamination

In OWL model, surgery examination process is described as shown in Figure 3, SurgeryExamination depends by RadiologyExamination. In Plan tag, “Enquiry” is set as “Examination”, which mainly collect the patient’ symptoms information, “Decision”is set as “further_investigation_decision”, and“Action” respectively are“Do_further_investigation”, “Manage_patient”, and“Discharge”. For example, when the system has made the decision about “further_investigation_decision”, it could produce an action about“Do_further_investigation” , which will be performed by SurgeonAgent.

```
<hasSubGoal>
  <OperationalGoal rdf:ID="SurgeryExamination">
    <dependsBy rdf:resource="#RadiologyExamination"/>
    <canAchievedBy>
      <Role rdf:ID="Surgeon">
        <registedAgent>
        <registedAgent>
        <registedAgent>
      </Role>
    </canAchievedBy>
    <hasAction>
      <Action rdf:ID="Do_further_investigation"/>
    </hasAction>
    <hasAction>
      <Action rdf:ID="Manage_patient"/>
    </hasAction>
    <hasAction>
      <Action rdf:ID="Discharge"/>
    </hasAction>
    <hasDecision>
      <Enquiry rdf:ID="further_investigation_decision"/>
    </hasDecision>
    <hasEnquiry>
      <Enquiry rdf:ID="examination"/>
    </hasEnquiry>
  </OperationalGoal>
</hasSubGoal>
</Goal>
```

Figure 3. a business model for the triple assessment.

3.2.2 RadiologyExamination

RadiologyExamination depends by BiopsyExamination. In Plan tag, “Decision” is set as “radiology_decision”, “Action” respectively are“Do_a_mammogram_of_both_breasts”and“Do_an_ultrasound_of_the_affected_area”. When the system has made the decision about “radiology_decison”, it could choose the right action accroding to the conditions that patients meet. For example, if a patient’age is greater than or equal to 35 and not

pregnant, the system could produce an action about “Do_a_mammogram_of_both_breast” , and it will be performed by RadiologyAgent.

3.2.3 BiopsyExamination

BiopsyExamination, In Plan tag, “ Enquiry ” is set as “ mammography_enquiry ” , “ Decision ” is set as “ biopsy_decision ” , “ Action ” are “ Fine_needle_aspirate ” , “No_biopsy_required” , “Send_for_guided_biopsy” ,and “Skin_biopsy” .

3.3 Model implementation process

Model implementation process under choreographer organizational mechanisms has the following five steps:

Step1: SurgenAgent accepts a referral message(Breast Cancer Referral) from GPAgent and then send a message which the content is TripleAssessment to choreographer.

Step2: choreographer accepts the message and performs its behavioural rule, parses the RegistrationModel.

Step3: choreographer finds the corresponding roles from the operational goals and look for the registered AgentGroups about the roles,then chooses the best agents.

Step4: All the agents chose by the choreographer will be form a medical team.

Step5: choreographer sends message to the team and notice them to complete the task.

For example, choreographer parses the current goal Surgery Examination and the role is Surgeon. The relevant Agent Group is Surgeon Agent Group with SurgeonAgent1, SurgeonAgent2, SurgeonAgent3. Choreographer gets the property values of all the agents and make an assessment for them to select the best one. After quantization of property values for each agent, the weighting value calculated for the optimal agent is SurgeonAgent3.The same as the operational goal of Radiology Examination and Pathology Examination.

After choreographer pick out a set of optimal agent, it will traverse the agents which can deal with the current goal and the next goal in accordance with the role. Health goals can be made up of complicated business flow structure in accordance with the order of the passing message. As shown in Figure 4. choreographer made a choice of decision.

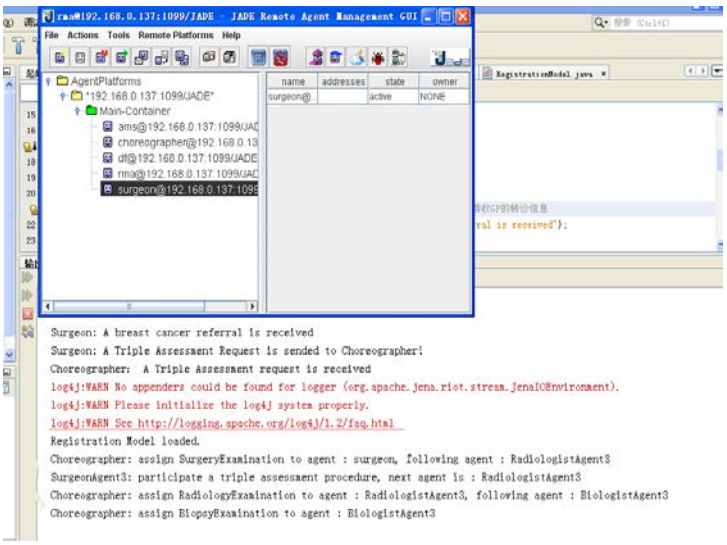

Figure 4. choreographer do a decision-making.

As shown in the above, Two agents are registered in the JADE platform, respectively is Surgeon, choreographer. Surgeon receives a message:“A breast cancer referral is received” and then send the message:“TripleAssessment” to choreographer. After choreographer receives the message, it starts the meta-model of Registration Model loaded and assigned the SurgeryExamination to SurgeonAgent3. SurgeonAgent3 will receive the message “participate a triple assessment procedure”. The following agent is RadiologistAgent3 means that choreographer assigned RadiologyExamination to RadiologistAgent3 and the last agent is BiologistAgent3 which is similar to BiologistAgent3.

4 Discussion & Future Work

How to coordinate different medical roles to participate in the diagnosis and treatment of complex disease have already become a major problem on the way to medical information. In this paper, A multi-agent coordination mechanism based on OWL is proposed to let different medical roles solve different medical problems together. we do a deep research on the description of rule and the organization of medical roles. At the same time we made some experimental results, but there are still some deficiencies. In subsequent studies, it can be improved from the following aspects:

[4] strengthen the research on the algorithm of agent selection. In a distributed environment, patients' demands are different so that the agent what the patient needs is different. We need to design a dynamic, flexible, specific requirements selection algorithm.

(2) In the experiment, the agents will have unusual circumstances during the execution of the task, such as agents to quit or suspend service, which requires coordination mechanism can have a real-time monitoring system, to make an quickly respond and an accurate decision-making process for the various problems. This will gradually be improved in future work.

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