A Semiotic Multi-Agent Modeling Approach for Clinical Pathway Management

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***Abstract*—Clinical pathway (CP) is the standard way to manage medical activities in order to improve the efficiency and minimize the cost of healthcare service. However current application of CPs can hardly adapt to the dynamic and complex clinical processes which involve the coordination of social agents in hospital. This paper focuses on developing a multi-agent modeling method to build up the system that can increase the execution efficiency of clinical pathway. In particular, we present a semiotic approach to analyze the requirement of clinical pathway. Furthermore we describe how the EDA (Epistemic, Deontic, and Axiological) agent and the negotiation model are realized and applied to support the clinical pathway management. Finally, the clinical pathway of breast cancer is presented to demonstrate our methods.**

***Index Terms*—clinical pathway, semiotics, multi-agent system, negotiation protocol, EDA agent**

I. INTRODUCTION

Nowadays, there are several continuing challenges in healthcare domain .On one hand, there is a growing demand for the high quality and efficient healthcare services provision, and on the other hand the cost of healthcare services has become an important area for the economic situation in most of the countries. In China, the total healthcare expenditure increased to 5150.3 billion in the year 2001 which account for 5.37% of GNP with a growth of 10% every year after that. The increase of healthcare expenditure has exceeded the increase of people's disposable income but the quality and efficiency of healthcare services can hardly satisfy people's requirement.

In order to improve the service quality and efficiency and minimize the resource cost, clinical pathway is developed as a standard way to manage medical activities since the 1980's.Clinical pathways (CP) are structured multi disciplinary care plans or medical processes in which diagnostic and therapeutic interventions performed for a particular diagnosis are described sequentially.

However, the application of CPs inevitably has some limitations of process management in practice [1]. They are designed by evidence and standard based method and then are applied in practice rigidly without considering the dynamic collaboration of their participations and the unpredictable situations. Therefore current CP management can not very well adapted to less structured and more complex clinical processes in dynamic hospital settings ,where the clinical process ,unlike the static and rigidly executed clinical pathway ,are made up of social agents such as physicians, departments with goals that they actively pursue in constant interaction with a network of other social agents.

A possible approach to improve clinical pathway management is the agent technology because its autonomy, social ability, proactiveness and responsiveness properties support the complex process which is conducted by the interactions among autonomous actors. Agent based simulation is a good way to explore clinical process and gain insights into the optimization potentials of clinical pathways that are difficult or impossible to investigate with other methods. Christian Heine et.al [2] present a system for agent based simulation and support for clinical process in to increase the efficiency of hospital process management. N. R. JENNINGS et.al developed an agent based infrastructure for managing business processes [3]. These researches above provide the mechanism to manage processes in complex and dynamic environment. However, previously to design a simulation model it is necessary to understand system requirement, using an adequate method for system

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analysis, which is always insufficient in current multi-agent approach for process improvement. High proportion of computer-based systems with the estimates varying between 40% and 50% fail because the requirement specifications are wrong [4].

Organizational Semiotics is a particular branch of Semiotics, the formal doctrine of signs [5]. The clinical process such as clinical pathway would then be seen as processes involving the creation, exchange and use of signs. In this paper, we propose an organizational semiotic approach to provide adequate system requirements and a solid conceptual basis for agent based clinical pathway management. Furthermore, the EDA agent model adopting the social norm concept found in the semiotics philosophical stance is introduced and the negotiation model and the way to construct multi-agent system are proposed. Our research provides a basis for designing the multi-agent simulation model to optimize CPs or the management system to control the CPs execution through the deep insight of their requirement.

II. Related Work

Semiotics, which was traditionally divided into three areas – syntax, semantics and pragmatics – has been extended by Stamper in order to incorporate three other levels, including a social world level [6]. The type of information signs studied in each level is informally and briefly described in Fig. 1.

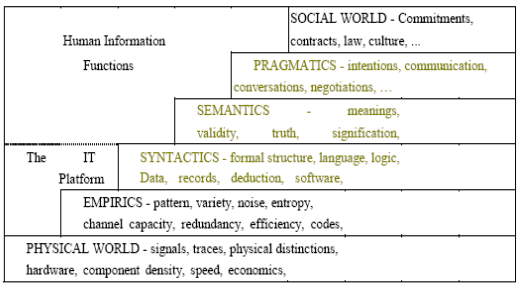

Figure 1. The Semiotics Framework

The clinical pathway, as we have mentioned, is the complex and dynamic medical process operated by the coordinated behaviors of social agents such as physicians, nurses, and other departments. They behave according to the norms such as responsibility, functions and commitment through the communication and collaboration during the creation, exchange and usage of signs, which cover the whole semiotics framework. Nevertheless, existing IT method for clinical process management such as the usage of workflow management system [7] [8] are mainly syntactic devices, as implied in the semiotics ladder in Fig. 1.Although they improve the efficiency of process management to some extent, they are rigid and can hardly adapt to different patients' situation. Syed SR ABIDI and Helen CHEN [9] presented a semantic web framework to generate and orchestrate patient-specific healthcare plans. Jiangbo Dang et.al [10] presents ontological knowledge frameworks that covers healthcare domains and use this framework for adaptive medical workflow. These researches are on the semantic level focusing on the meaning and concept of clinical processes which support the personalized design of healthcare plan but can hardly improve the schedule of the real process execution dynamically. Christian Heine et.al [2] present a system of multi-agent based simulation for clinical process to increase the efficiency of the distributed hospital process management through coordination taking into consideration of predefined quality criterions, partly on the pragmatics level. However an adequate understanding, from semantic to social level, of the requirement for clinical pathway management and the social norm which govern the behaviors in the process are still needed to construct the simulation model precisely and optimize the process more effectively.

In contrast, this paper advances the state of art by (1) providing an adequate understanding on clinical pathway from semantic level to social level through semiotic methods; (2) bridging the gap between the computer system and clinical pathway by using the organizational semiotics methods as the knowledge basis for our agent model (3) providing a negotiation model from the speech act scenario of the negotiation process for the scheduling of activities in the clinical pathway.

III. Semantic Analysis

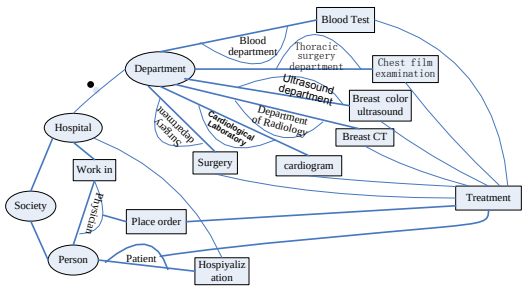

Figure2. The ontology chart for the clinical pathway for breast

Semantic analysis is the methodology in Organizational Semiotics that approach the requirements analysis of information system by focusing on the semantics level first and then building up towards the social world level[11]. This method consists of a negotiated understanding of the meanings of domain specific signs, including agents, concepts, relationships, patterns of behaviors and other related aspects in the processes. There are three important concepts in semantic analysis: agent, role and affordance. The result of semantic analysis may be provided in a graphical format, using what is called 'ontology chart', as shown in an example of clinical pathway for breast cancer in Fig. 2.

An agent (represented as ellipses) is responsible for controlling the existence of other entities using the following three operations: bring into existence, maintain and terminate [12] guided by organizational norms but,

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since the agent may choose to violate norms, he always retains autonomy. A role (represented as half circles) is always associated with an agent that undertakes responsibilities and defined with respect to the role carrier on its left and the concept determining the responsibility on its right. An agent may have several roles. The affordance concept (represented as rectangles), introduced by Gibson, is an invariant that is perceived by an agent and is used to express the collection of patterns of behavior which define an object or a potential action available to members of society. In our research, affordance can be applied to represent the behaviors in clinical process.

The relationships between two concepts such as the relationship between "hospital" and "department" is ontological dependency which defines the existence of the first in terms of the existence of the second, for example "hospital" is the ontological antecedent and "department" is the ontological dependent. The dot sign means that the ontology dependency is that of part to whole.

Through the semantic analysis, we can represent the agent, role, affordance and their ontological dependency in clinical pathway by ontology chart which delineates the boundary of concern in the analysis and defines the meaning of terminology used in the clinical pathway model. In this way, misunderstanding caused by interdisciplinary communications is avoided. Furthermore semantic analysis places an emphasis on the ontological dependency which ensures a rigorous process of analysis and specification. In doing so, a rigorous analytical principle of ontology constraint must be observed that a pattern of behavior can be described only if the agent who acts is described in the model. That principle enables the correctness of clinical pathway model. The essential advantage of ontology charts over, for example, Entity-Relationship (ER) models lies on that ontological dependency shown only on ontology charts are less prone to change than entity relationships. Ontology charts provide a way to establish the semantics of very stable relationships in an organizational environment [13].

IV. Norm Analysis

The ontology chart shows the existing entities and their ontological dependencies in the clinical pathway but not the sequence of the activities namely the starting and finishing times of each one of them. The dynamics of the clinical pathway, established by these start and finish events, may be determined either by norms or by agents taking responsibility and exercising discretion. All the regulated aspects that guide activities in the clinical pathway are defined by norms. Norm analysis is a method to identify and represent the norms in the ontology chart which govern the agent's behaviors in the social context by determining whether certain patterns of behaviors are acceptable or legal in the problem domain.

The clinical pathway can be described by combining the ontology chart and norms. For example, for the clinical pathway of breast cancer, the hospitalization triggers this pathway, then placing order, examinations, treatment and eventually discharge. The details describing the start and finish of these affordances in the ontology chart, referring to socially accepted permissions, obligations or prohibitions can be described by norms. For example, one of the behavioral norms in the clinical pathway of breast cancer is as follows:

Norm1: IF a patient x originates a request for breast CT THEN the radiology department OUGHT to perform the breast CT for this patient within 1 days; the sanction σ for not doing so is the loss of reputation.

According to how norms control human behavior, four types of norms can be identified as [14]: perceptual norms, cognitive norms, evaluative norms and behavioral norms. Perceptual norms deal with how people receive signals from environment. Evaluative norms explain the value and preferences of people and affect the behavioral norms. Behavioral norms govern people's behavior within regular patterns and also influence evaluative norms .Cognitive norms enable one to incorporate the beliefs and knowledge to interpret what is perceived and to gain an understanding based on existing knowledge. Perceptual, evaluative and cognitive norms affect human's behavior by influencing behavioral norms .In this paper, we consider the comprehensive effect of these norms on the management of clinical pathway through EDA agent.

V. The Clinical Pathway as the Collaborating and Negotiating Agents

As we have discussed above, the clinical pathway can be seen as an activity network composed of autonomous agents. Agents represent individuals, such as the patient, physician, and nurse, and collectives such as the radiotherapy department, oncology department and other department or groups in the hospital. From the semiotic perspective, the signs created, exchanged and used in the clinical process affect the behaviors of the involved agents through the guidance of norms .This principle can be applied to how intelligent agents operate for the management of clinical processes. The norms are represented and stored in agents, which continually perceives the signs and compare them with norms serving for coordinated behaviors.

In Autonomous Agents research, the EDA model, which is norm based and incorporate social attitudes and semiotic principles, has a direct relationship in its component (Epistemic, Deontic and Axiological) with the types of norms we have discussed before. Unlike other multi-agent systems approaches , which mainly focus on the design of the internal structures of single agent, the EDA model emphasize on the social structure that underlies multi-agent cooperation. This emphasis on social agency help agents coordinated depending on its context in the process involving the creation and exchange of signs [15] and thus makes it more flexible to simulate the complex clinical process. In our research we build our agent internal architecture based on EDA model as shown in Fig. 3 and the agents in the system undertake different roles to collaborate congruently which are detailed later in the text.

A. Agent Architecture

Knowledgebase: The EDA model serves as the knowledge base of the agents which enables the representation of agent informational states and

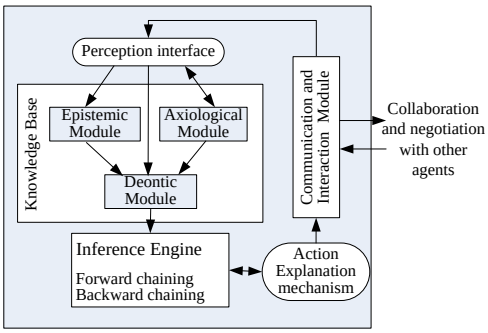

Figure 3. The internal agent architecture

simultaneously defines the conceptual communication framework that support the collaborative activities in the clinical pathway. Its structure is based on three components: the Epistemic, the Deontic, and the Axiologic.

The epistemic component stores the existing knowledge concerning both the agent himself and his acquaintance agents. All statements concerning the beliefs and capabilities of the agent himself and the statements describing what this agent believes other agents can do and believes are represented in it. Cognitive norms are represented as conditional beliefs, for example the rules. We can acquire this knowledge from the ontology chart through semantic analysis but represent them in a formal model in order to partially automate some of the clinical pathway .Here we let $\mathcal{A} = \{\alpha_1, \alpha_2 \cdots, \alpha_k\}$be the set of agents and let be the set of affordance represented in the ontology chart. Let be the set of relationships between them. Each ontological relationship is represented as $\rho_i = \{antecedent, subsequent\}$ .Here the subsequent is the agent or affordance that depend on the antecedent agent or affordance. An affordance may depend ontologically on one or two antecedents.

The deontic component is where all the possible behaviors of the agent are defined. Here the norms, commitments, agent's behaviors and plans, i.e. the clinical process ,that describe the dynamics of the ontology obtained through norm analysis we discussed in the last section are represented in a unified way as generalized goals. The detailed expressive modal representation for goals can be found at [16].This component can be used to describe how single tasks are composed to a treatment plan and it can specify order restrictions and possible parallel sequences in the clinical pathway.

The axiological component provides preference relations both for the deontic component and for the epistemic component that would enable to solve dubious or conflicting situations. This component permanently computes utilities associated to deontic norms and suggest the best agent's next action. This component acts respecting the whishes of agents involved in the clinical pathway such as patient's restrictions and preferences.

Perceptual Interface: The perceptual interface continually perceives the signs created during the agents' coordination in the clinical process from the communication and interaction module and send the information to the knowledge base. This interface provides the pragmatic function that filters perceptions, according to the agent perceptual and axiological norms, and updates one or more model components in the knowledge base.

Interface Engine: As we have discussed before that the behaviors and the norms that describe how these behaviors occur in the clinical process are defined in the deontic component as the generalized goals. The inference engine is responsible for planning activity by the rule-based paradigm for representing means-ends process. This process is based on a process of goal decomposition and sequencing using a backward chaining inference process, over rule sets where rule antecedents represent less general goals and consequents represent more general goals. The inference engine computes the action plan and sends to the communication and interaction module.

Communication and interaction module: This model has two main functions. Firstly, it communicates messages between an agent and other agents or resource objects during task management, service collaboration and negotiation. Secondly, it provides services through negotiation. The knowledge base invokes this module to begin negotiation for services the agent needs. The negotiation capability is supported by the capability knowledge of the agent itself and its acquaintances'. The contract net protocol is adopted as negotiation mechanism stored in this module.

In a summary, we use the organizational semiotics methods as the knowledge basis for our agent model: Semantic analysis, through the resulting ontology chart, defines most of the epistemic component of the EDA model; Norm analysis provides a model for the dynamics of the clinical pathway, defining the start and finish of

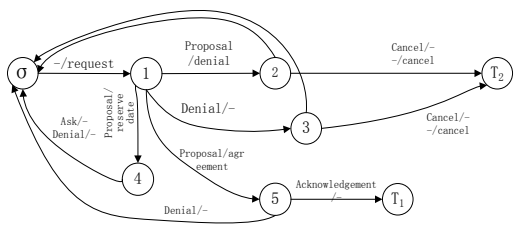

Figure 4. STDS diagram for the negotiation protocol of service initiator

agent instances and affordances identified in the ontology chart, which can be represented in the epistemic, deontic or axiologic components in the agent. We model the multi-agent system for clinical pathway management based on the results from semantic analysis and norm analysis, to focus on the pragmatics and social organizational semiotics levels. Therefore our approach can provide adequate system requirement covering from

semantic level to social level as the solid conceptual basis for agent based clinical pathway management.

B. The Roles, Services and Policy to Construct the Clinical Pathway Multi-agent System

The clinical pathway is the process that executed by the coordination and collaboration of agents with different roles, such as the physician, patient and other departments, by which endues the agents with different responsibilities and policies. Therefore the clinical pathway can be interpreted as a set collection of hospital

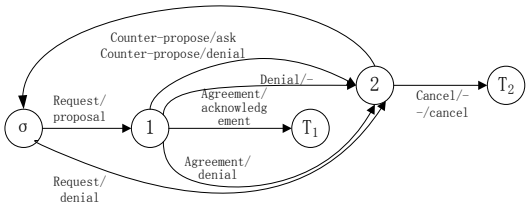

Figure 5. STDS diagram for the negotiation protocol of service provider

roles that co-ordinate their activities in order to accomplish the goal of treating patient's disease.

We construct the multi-agent system based on the role definitions in the clinical pathway, which are defined in the ontology chart and described in terms of the services and policies assigned to these roles. The services are defined in terms of agent abilities, i.e. the services the agent can provide such as the blood test; therefore they are stored in the epistemic component as procedural knowledge. Policies are a set of rules related to one or more EDA components determining the normative goals of the role and are interpreted as normative knowledge in the deontic component. The declarative representation in the deontic component enables the usage of a deductive inference process. So the roles involved in the clinical pathway can be uploaded to the EDA agent by receiving a set of rules especially when certain service are needed or the participation of a negotiation with another agent is required.

C. Negotiation Model

The execution of clinical pathway includes many services such as examinations or treatments which are executed by different departments so that there need huge amount of negotiation to make arrangement between these services provider agents (physician or other department) and the service request agents (patient),which is a sophisticated work because a lot of constraints. The first is the scheduling problem of patient. Since a clinical pathway is associated with a specific patient for whom a single service may be a part of his clinical pathway, the scheduling has to satisfy several temporal restrictions. Secondly, many treatments and examinations services in the clinical pathway are provided by different departments that autonomously manage their time plans. The involved agents from different departments have to negotiate for the service they need considering their own restrictions and preferences.

We adopt the speech act perspective to design the negotiation protocol. A speech act can be seen as an utterance with effects in the environment of the speaker. We use the real episode of negotiation according to [17] for scheduling in hospitals to make suitable negotiation protocol. Five speech acts are used: request, proposal, agreement, acknowledgement and denial. The design of negotiation protocol is made using syntax-directed translation schema (STDS) and attributed grammars[18].Two STDS diagrams are developed to for

σ ::=λ N_1, request N_1
N1::=ProposalN2, DenialN2 |DenialN3, λ
N3|ProposalN5, agreementN5|ProposalN4, ReserveN4
N2::= λ σ , λ σ |cancelT2, λ T2|λ T2, cancelT2
N3: : =λ σ , λ σ |cancelT2, λ T2|λ T2, cancelT2
N4::=askσ , λ σ |denialσ , λ σ
N5::=AcknowledgementT1, λ T1|Denialσ , λ σ

Figure.6 SDTS grammar for the negotiation protocol of service

the initiator and the reactor to specify the negotiation protocol. Fig. 4 and Fig. 5 show the protocol for the service demander and reactor of negotiation respectively.

In these figures, nodes T1 and T2 represent terminal nodes for successful and unsuccessful transactions, respectively. The words above the arrow lines between the nodes represent the input and output for the initiator and provider Nodes with sequence number 1, 2 and so on (denoted by N_i in the form of norms) are permitted transitions between the input and output reflecting the pragmatics of the speech acts (expected next action or speech act) correspond to the decisions and actions during the negotiation. σ denotes the start symbol of the

σ :: =requestN1, proposalN1|requestN2, denialN2
N1::=reservationN2, askN2|reservationN2, denialN2|denialN2, λ
N2|agreementT1, askT1|agreementN2, denialN2
N2::= λ σ , λ σ |cancelT2, λ T2|λ T2, cancelT2

Figure.7 STDS grammar for the negotiation protocol of service provider

negotiation.

Fig. 6 and Fig. 7 show the SDTS for the protocol of service requester and service provider. λ denotes the null string.

Although we adopt the SDTS formalism to represent the negotiation model used by the interacting agents in the clinical pathway, unlike methods that directly implement finite-state machine process descriptions, we describe the negotiation mechanism as a set of norms, instead of a sequence of actions, based on a pragmatic interpretation of the constituent speech acts effects. Norms are more flexible than a sequence when changes are required. We can add, change or remove norms from the norm-set without much concern with the overall interactions. This is due to a separation between the declarative knowledge that refers to what the norms are,

from the procedural knowledge of how to use the norms. Fig.8 and Fig.9 shows the norm sets corresponding to the Ni norms in figure 5 and 6 for the negotiation protocol of service initiator and provider respectively.

Among many negotiation protocols, the most famous negotiation protocol is the contract net protocol, inspired by contracting process in human organization and used in many domains. However this model fails to capture many intuitive and important aspects of the negotiation process including concession and the modification for new alternatives. In our work, besides the flexibility of the norm based negotiation model, our protocol represents a more practical negotiation process in our real clinical pathway. In our work, besides the flexibility of the norm based negotiation model, our protocol represents a more practical negotiation process in our real clinical pathway covering the semantic and pragmatic level in the clinical pathway and including all the possible negotiation scenarios to fix when the treatment and examination in the clinical pathway should be executed.

σ: **IF** the provider receive a request and find a proposal with its restrictions **THEN** send the proposal to initiator

IF the provider receive a request but cannot find a proposal **THEN** sends denial to initiator

N1:**IF** the provider receive counter-propose and does not allow the counter-propose **THEN** send denial to initiator

IF the provider receive counter-propose and allow the counter-propose **THEN** send ask to initiator and memorize the counter-propose

IF the provider receives the denial from initiator **THEN** go to execute N2:

IF the provider receive the agreement about the proposal and consider it all right **THEN** send the acknowledge, make entry in clinical pathway and end the negotiation

IF the provider receives the agreement about the proposal and doesn't consider it all right **THEN** send denial to initiator

N2: Go to the start point

IF the negotiation exceed the maximal response time THEN send cancel to end the negotiation

IF the initiator receives the cancel message from the provider **THEN** end the negotiation

Figure 9. The norm set for the negotiation protocol of service provider

VI. THE MULTI –AGENT SYSTEM FOR CLINICAL PATHWAY OF BREAST CANCER

Here we model the multi-agent system to manage the clinical pathway of breast cancer which is a complex process consisting of many tasks such as surgery, cardiogram, breast CT, breast color ultrasound, chest film examination, blood test and other tasks provided by different departments such as surgery department, cardiological laboratory, ultrasound department, thoracic surgery department and blood department.

A. Clinical Pathway Descriptions

The clinical pathway of breast cancer start from the day the patient enter into the hospital, the physician place examination order according to patient's situation, then the patient execute these examinations listed on the order which may include cardiogram, breast CT, breast color ultrasound, chest film examination, blood test and other tests if needed .After the examination, the physician will arrange the surgery for the patient according to the test results. In the breast cancer clinical pathway, the earliest surgery day can be at the third day and the latest day can be the seventh day of the hospitalization. Finally, the patient may discharge if his health situation satisfies the discharging criteria.

B. Ontology Chart

Through the semantic analysis for the clinical pathway of breast cancer, we get the ontology chart as the general understanding of the clinical pathway for the agents acting in the pathway about which agent perform what role and what behavior they afford as the conceptual basis for the multi-agent system. The ontology chart for clinical pathway of breast cancer is depicted in Fig. 2

C. Roles

There are 8 roles in this clinical pathway and they are patient, physician, surgery department, cardiological laboratory, ultrasound department, thoracic surgery department and blood department. Each role provides a set of services and policies according to their responsibility in the pathway. We will take the role *radiology department* as example.

The services are describes in the form of beliefs in the epistemic module .As we can see from the ontology chart, the role *radiology department* afford the service *"breast CT"*, which can be represented as follows:

service (name breast CT)
(goal breast CT done)
(input :Patient ID, Physician order)
(output: test_result)
(plan plan1)
(cost :price ,duration))

The plan 1 is the negotiation process which the radiology department uses to react to the request for the service *breast CT* in order to scheduling the appointment to execute the test. The negotiation process is represented in the form of STDS and stored as norms as discussed in V.

The policy is the norms imposed by the hospital to the agent according to different role. The policy imposed to role *radiology department* is as follows:

IF the radiology department receive a request for breast CT from a patient THEN it must accept the commitment to get the CT finished within 4 hours. And if this rule is violated this will lead to 200 sanction imposed by the hospital.

D. The collaborative and negotiating agents for clinical pathway of breast cancer

In Fig.10 we show the multi-agent system for breast cancer clinical pathway management using EDA paradigm, bring together the notions we discussed in the above sections.

σ :Send request to service provider

N1:**IF** the proposal from the provider is not acceptable THEN send the denial message

IF the initiator receives denial message from provider THEN go to execute N3

IF the proposal from the provider is acceptable and the initiator does not continue negotiation **THEN** send agreement to provider

IF the initiator accept the proposal from the provider but want to continue negotiation **THEN** send the reserve message to provider

N2: **IF** the initiator wants to continue negotiation **THEN** tightens restrictions and goes to the start point

IF the initiator does not want to continue negotiation or exceed the maximal response time **THEN** send cancel message to end the negotiation

IF the initiator receives the cancel message from the provider **THEN** end the negotiation

N3: **IF** the initiator wants to continue negotiation **THEN** eases the restriction and goes to the start point.

IF the initiator does not want to continue negotiation or exceed the maximal response time **THEN** send cancel message to end the negotiation

IF the initiator receives the cancel message from the provider THEN end the negotiation

N4: IF the initiator receives ask or denial message from provider THEN go to the start pointσ

N5: IF the initiator receives acknowledgement from provider THEN make entry in the clinical pathway and end the negotiation.

Figure.8 The norm set for the negotiation protocol of service initiator

VII. CONCLUSION

Clinical pathway is the standard treatment plan to manage medical activities in order to improve the efficiency and minimize the cost. However, the clinical pathways are complex process involving the coordinated activities among different autonomous social agents with their own goals and restrictions. Agent technology is able to handle the hospital dynamics as well as complex clinical pathways with restrictive requirement. In this research, we propose a semiotic approach to model multi-agent system for clinical pathway management. We improve the modeling method of agent system by providing adequate system requirements and a solid conceptual basis for agent based clinical pathway management through ontology chart and norms. We introduced the EDA agent model which adopting social norm concept in semiotics as our agent architecture and propose the negotiation model from speech act perspective for the scheduling of the services in the clinical pathway.

Therefore, our work has made a contribution to manage clinical pathway from semiotic perspective by capturing all necessary knowledge from syntactic level to social level and guiding the modeling of the multi-agent system. The method proposed in this paper can be used as the way to design the multi-agent simulation model for clinical pathway optimization or the management system for the control of clinical pathway execution. Both applications will be evaluated with respect to the advantage of semiotic multi-agent approach over the traditional clinical pathway management methods.

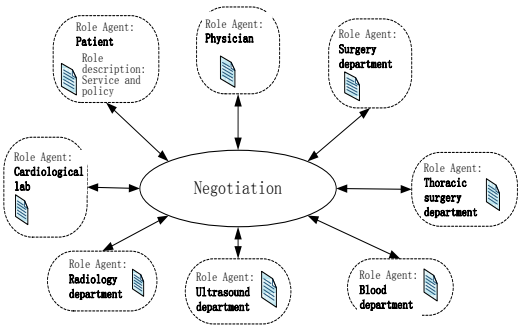

Figure 10. The multi-agent system architecture for breast cancer clinical pathway

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REFERENCES

[1] Weizi Li, Kecheng Liu ,Shuzhang Li, Hongqiao Yang .Normative Modeling for Personalized Clinical Pathway using Organizational Semiotics Methods, *Proceedings of International Symposium on Computer Science and Computational Technology,* ISCSCT '08,Shanghai.Volume2,20-22 Dec.2008 Page(s):3–7

[2] Heine, C., Herrler, R. and Kirn, S. (2005) ADAPT@AGENT.HOSPITAL: Agent-based Optimization and Management of Clinical Processes, *International Journal of Intelligent Information Technologies (IJIIT)*, 1, 1, 30-48.

[3] Jennings, N. R. and Faratin, P. and Johnson, M. J. and Norman, T. J. and Wiegand, M. E. (1996)Agent-based business process management. I*nternational Journal of Cooperative Information Systems*, 5(2):05-130

[4] Stamper, R., K. Liu, M. Hafkamp and Y. Ades, 2000. Understanding the Roles of Signs and Norms in Organizations – a Semiotic Approach to Information Systems Design, *Behavior and Information Technology*, 19(1), 15-27.

[5] Peirce, C. 1960. Collected papers of Ch. S. Peirce (1931-1935), C. Hartshorne and P. Weiss (Eds). Cambridge, Mass

[6] Stamper, R., 1973. Information in Business and Administrative Systems. John Wiley & Sons

[7] R. Lenza,, R. Blaserb, M. Beyerb, O. Hegerb, C. Biberc, M. Baumleinc, M. Schnabelc. IT support for clinical pathways — Lessons learned. International journal of medical informatics 76S(2007)S397 – S402

[8] Richard Lenz , Manfred Reichert. IT support for healthcare processes – premises, challenges, perspectives. *Data & Knowledge Engineering* 61 (2007) 39 – 58

[9] SSR ABIDI, H Chen. Adaptable Personalized Care Planning via a Semantic Web Framework. *Proc. 20th International Congress of the European Federation for Medical Informatics (MIE'2006)*, IOS Press,Aug. 2006.
[10] Jiangbo Dang , Amir Hedayati, Ken Hampel, Candemir Toklu. An ontological knowledge framework for adaptive medical workflow. *Journal of Biomedical Informatics*,2008.
[11] Joaquim Filipe, The EDA Model: An Organizational Semiotics Perspective to Norm-based Agent Design, *Workshop on Norms and Institutions in Multi-agent systems at Normative agent*, June 2000
[12] Liu, K., 2000. Semiotics Information Systems Engineering. Cambridge University Press. Cambridge.
[13] Joaquim Filipe, NORMAJINI: a norm-based multi-agent system architecture using JINI. Workshop on Norms and Institutions in Multi-agent systems at Normative agent, June 2000
[14] Weizi Li,Kecheng Liu, Shuzhang Li,Hongqiao Yang. Norm Based Agent for Generating Personalized Process, *The 11th International Conference on Informatics and Semiotics in Organisations,* IFIP WG8.1 Working Conference, ICISO 2009
[15] Darren Booy, Kecheng Liu., Bing Qiao, Chris Guy (2008) A Semiotic Multi-Agent System for Intelligent Building Control. *Proceedings of the IEEE/WIC/ACM international conference on Intelligent Agent Technology*: 653-659 Quebec, Canada
[16] Filipe, J. (2000) Normative Organisational Modelling using Intelligent Multi-Agent Systems. Ph.D.thesis, University of Staffordshire, UK
[17] Herrler, R., Heine, C. & Klügl, F. (2002) Appointment Scheduling Among Agents: A Case Study In Designing Suitable Interaction Protocols. *In: AMCIS 2002 Proceedings*, S. 1456-1463, Dallas.
[18] Fred A. and J. Filipe, 2000. Syntax-Directed Translation Schemes For Multi-Agent Systems Conversation Modeling. ICEIS 2000, Stafford, UK.

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W Li, K Liu, S Li, H Yang, Normative Modeling for Personalized Clinical Pathway Using Organizational Semiotics Methods, *International Symposium on Computer Science and Computational Technology*, pp.3-7,2008.

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Liu, K., R. Clarke, P. Anderson, R. Stamper (eds) with El-Sayed Abou-Zeid (2002a) *Organizational Semiotics: evolving a science of information systems*, Proceedings of IFIP WG8.1 Working Conference, Kluwer Academic Publishers, Boston, ISBN: 1402071892

Liu, K., R. Clarke, P. Anderson, R. Stamper (eds) (2002b) *Coordination and Communication using Signs: Studies in Organisational Semiotics* - 2, Kluwer Academic Publishers, Boston, ISBN: 0792375092

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