AN AGENT-BASED SYSTEM FOR HEALTHCARE PROCESS MANAGEMENT

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Abstract: An effective approach for healthcare process management is the key to delivery of high-quality services in healthcare. An agent-based and process-oriented system is presented in this study to facilitate dynamic and interactive processes in healthcare environment. The system is developed in three layers: the agent layer for healthcare process management, the database layer for maintenance of medical records and knowledge, and the interface layer for human-computer interaction. The treatment of primary open angle glaucoma is used as an example to demonstrate the effectiveness of approach.

1 INTRODUCTION

In healthcare organizations, there are a variety of processes, such as hospital administration by managers, registration for treatment by patients, test report generation by technicians, and diagnosis decision making by doctors. There is a trend to view healthcare in a multidisciplinary perspective, as numerous interactions and cooperation take place across different functional units in terms of information sharing, consultation, and combined treatments. These interactive and collaborative activities should be well organized and managed, without which the efficiency of healthcare service cannot be easily guaranteed. To meet these requirements, a process-oriented and cooperation-supported healthcare system is needed, especially with computer and information technology support.

To facilitate healthcare process management, workflow technology (van der Aalst and van Hee, 2002) has been applied in a number of studies (Lenz and Reichert, 2007). In the recent years, organizational environments have been changing from stable-and-closed to dynamic-and-open. Business processes are becoming increasingly complex and dynamic as they seek to cope with a wide range of internal and external interactions and changes. Traditional workflow technologies for process management are often inadequate for complex and dynamic situations due to the lack of flexibility and adaptability (Wang and Wang, 2006). This change has also happened in the healthcare sector. Frequent changes of clinical pathways and increased interactions between different units have become a big challenge in healthcare process management. This change has also happened in the healthcare sector. Due to newly discovered symptoms of a specific disease or need of further diagnosis, pre-planned clinical schedules always request adjustment; ad hoc changes of medical process are needed during execution. Besides, to fulfill a simple task such as gonioscopy for glaucoma diagnosis, cooperation among different functional units is required. In sum, frequent changes of clinical pathways and increased interactions between different units have become a big challenge in healthcare process management.

To develop a computer-based system that enables effective process management in healthcare, an agent-based cognitive approach is presented in this study. The term “agent” refers to a piece of software that can perceive its environment through its sensors and can act upon that environment through the effectors (Wooldridge and Jennings, 1997). A healthcare management unit has similar characteristics with software agent, which has a set

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of goals (e.g., treatment effects and costs), perceptions of the environment (e.g., symptoms and records), and actions to take (e.g., recommendations for test or treatment, and inquiry).The highly dynamic and unpredictable nature of organizational processes makes agent-based approaches appealing. Using agent-based technology, we may decompose a complex process into a number of loosely coupled tasks and delegate the tasks to a number of software agents, each of which works autonomously and collaboratively in performing tasks and managing the whole process (Wang and Wang, 2006).

In this study, an agent-based and process-oriented healthcare system is developed. The system consists of three layers, the agent layer for healthcare process management, the database layer for maintenance of medical records and knowledge, and the interface layer for human-computer interaction. The emphasis is placed on dynamic clinical and administrative process management, and knowledge building as the foundation for process management. This agent-based and process-oriented healthcare system distinguishes from other healthcare systems in terms of continuous awareness of the healthcare environment, real-time dynamic decision making of healthcare processes, and rule-based knowledge engineering. The treatment of primary open angle glaucoma (POAG) is used as an example to demonstrate the effectiveness of this approach.

2 SYSTEM ARCHITECTURE

To meet the requirements arising from dynamic processes and cooperative functions in healthcare, an agent-based healthcare process management system is presented with a three-layer architecture.

2.1 Interface Layer

This layer supports various interactions between human users (administrators, doctors, nurses, and medical technicians) and the computer system. Different type of user may access and interact with the system through specific interfaces.

2.2 Agent Layer

In the system, a group of software agents are proposed to perform healthcare tasks. Various interactions take place between the autonomous agents or between the agents and human users including doctors, nurses, technicians, and administrators. The design of software agents is process-oriented, i.e., agents are able to execute tasks according to process rules. What's more, process rules can be edited in a graphical form, which makes it easy to specify and update the rules. The details of each agent are elaborated as follows.

Clinical Decision Agent works with doctors. It consists of three components: a knowledge base that captures glaucoma knowledge into a set of rules for clinical diagnosis decision making; a reasoning engine that generates diagnosis decision or treatment recommendations based on patient records and test results; and an interpreter that interprets the decisions or recommendations generated by the computer.

Patient Management Agent works with clinical administrators and nurses, managing patient records and coordinating treatment processes. It also interacts with other agents for communication of patient records, test reports, and treatment records throughout the healthcare process.

Medical Examination Agent works with doctors, medical technicians, or nurses, as well as communicates with Patient Management Agent and Clinical Decision Agent throughout the medical examination process. The medical examination process may go through several steps including patient records access, test scheduling, notification and reminder, and finally test report generation and delivery.

Ward Treatment Agent works with doctors and nurses, as well as communicates with Patient Management Agent or Clinical Decision Agent during the inpatient treatment process. The activities include treatment scheduling, notification and reminder, information inquiry, and treatment report generation and delivery. The agent also maintains the information of treatment activities, progress, and patient states during the treatment process.

Operation Agent works with doctors and nurses, as well as communicates with Patient Management Agent or Clinical Decision Agent to manage the operation process. The process may go through several steps including patient records retrieval, operation scheduling, notification and reminder, and operation report generation and delivery.

2.3 Database Layer

Medical information is stored in a database to support the healthcare functions. The information includes patient records, treatment records, examination records, diagnostic knowledge, and treatment knowledge. Considering information security and maintenance issue, different agents are

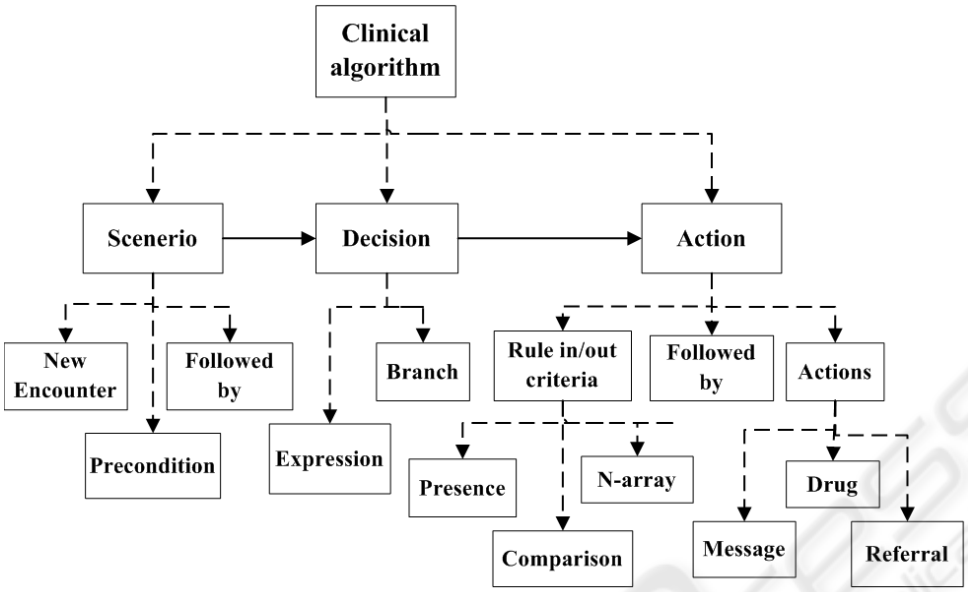

Figure 1: Hierarchy of clinical algorithm ontology.

associated with different data, with different rights to access or update the data. For example, Patient Management Agent has the right to access patient records; while other agents can acquire patient records via communication with Patient Management Agent. Differing from data records, knowledge for clinical and administrative process management is more complicated. Relevant techniques and tools are used to capture and model the knowledge into a set of rules or guidelines.

3 KNOWLEDGE-BASED PROCESS MANAGEMENT

To facilitate dynamic and interactive clinical processes, we need to capture a large amount of information and knowledge as the foundation for process management. In addition to clinical information such as patient records and treatment data, it is crucial to identify or set up the rules or guidelines as the knowledge for diagnosis and treatment decision making and clinical administration. To capture and represent the knowledge in the system, ontology-based technology is adopted in this study. Using ontology, the narrative paper based guidelines or rules are encoded into computerized specifications. To build the ontology, we use Protégé (O'Connor et al., 2007) as the ontology representation tool. Protégé is a free and open-source platform that provides a suite of tools to construct domain models and knowledge-based applications with ontology. In developing the proposed system, we use Protégé for knowledge building by way of class modelling, goal and criteria building, clinical algorithm construction.

In this study, we choose glaucoma treatment as an example to demonstrate the proposed approach. Glaucoma is a leading cause of blindness in most countries; the irreparable loss of vision by glaucoma requires lifelong healthcare. Meanwhile, the disease of glaucoma is well investigated; the process of the treatment is documented as various kinds of guidelines that can be used as reference for knowledge building in this case. There are many types of glaucoma, from which we choose the primary open angle glaucoma (POAG) for illustration.

3.1 Knowledge Modelling

We model the rules or guidelines for clinical decision-making into clinical algorithms (see Figure 1). Based on the clinical algorithms, recommendations such as messages, drugs, and referrals can be generated for diagnosis, treatment, and other clinical process.

Each algorithm includes three nodes: scenario, decision, and action. *Scenarios* are mutually exclusive entry points for clinical algorithms, which exhibit unambiguous definition of patient states. A scenario contains several major properties called slots: a) the new encounter slot is used to enable/disable this scenario as a starting point; b) the precondition slot is to qualify the scenario as a

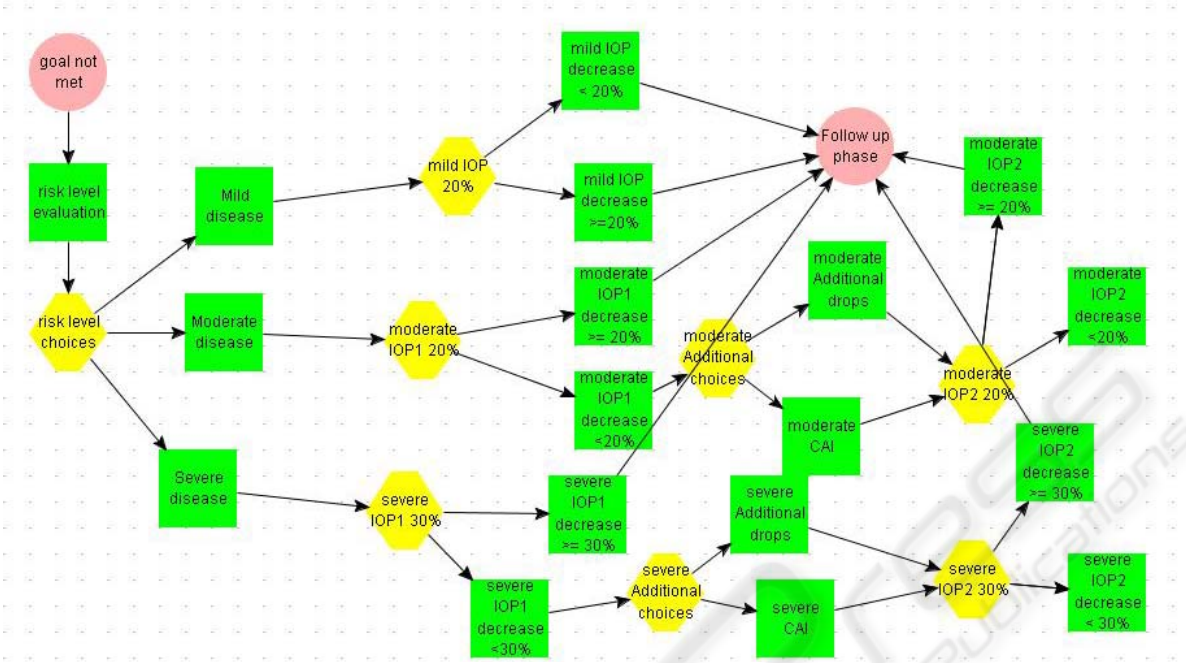

Figure 2: POAG treatment algorithm after topical therapy.

starting point; and c) the followed by slot is a next step in the algorithm. A *decision* node contains: a) a choice step (e.g., severe IOP1 decrease <30%) which may lead to more than one choice; or b) a case step which has an evaluated expression to enable the execution of the next step node. An *action* is a node with a rule in/out criteria slot (e.g., if risk level = severe and IOP decrease >= 30%) and a defined action slot (e.g., Filtration surgery) in forms of message, drug recommendations, or referrals.

3.2 Knowledge-based Clinical Process

The diagnosis and treatment process of glaucoma can be divided into several steps:

1) Comprehensive eye examination should be carried out to differentiate POAG or suspect.
2) Further examinations are taken for establishing a baseline of intraocular pressure (IOP) and designing the initial treatment.
3) After establishing a good baseline, it is obliged to set up a reasonable goal of intraocular pressure (IOP).
4) Based on the goal established in step 3, an initial topical therapy is carried out to lower the pressure.
5) If necessary, follow-up treatment is required after the initial topical therapy. Due to the space limitation, we only provide details of step 5 as follows.

In the initial treatment of POAG (step 4), the first step topical therapy may not reach the initial intraocular pressure goal. Therefore, treatment algorithm after topical therapy (Hodapp et al., 1993) should be followed. Figure 2 shows the modeling of this specific algorithm in Protégé. Pink circle indicates a scenario; yellow polygon indicates a decision; and green square indicates an action choice.

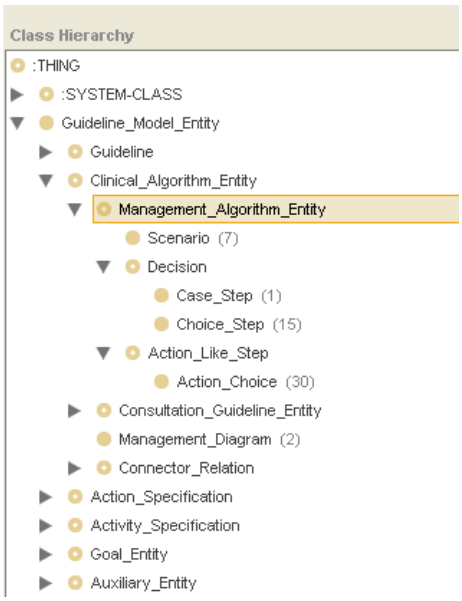

Figure 3: Class hierarchy in Protégé.

They are linked by one direction arrow to show a follow-up relation with each other and form an algorithm chart. After implementation, the POAG treatment algorithm after topical therapy is represented as an instance of Management Algorithm Entity shown in Figure 3. The pink circles, yellow polygons, and green squares in Figure 2 are mapped to three subclasses (Scenario, Choice step, and Action Choice) of Management Algorithm Entity, respectively in Figure 3.

4 SYSTEM IMPLEMENTATION

In our system, five agents are developed, Patient Management Agent, Medical Examination Agent, Ward Treatment Agent, Operation Agent, and Clinical Decision Agent. For implementation of a multi-agent system, we adopted JADE (Bellifemine et al., 2007), a widely used open source middleware developed by TILAB for the development of distributed multi-agent applications based on the peer-to-peer communication architecture.

In addition to multi-agent architecture, the implementation concerns the individual agent. After specifying clinical guidelines and process rules using Protégé, we use a plug-in called beangenerator, implemented by C.J. van Aart, to create the ontology definition class and the predicates, agent actions, and concepts classes (Caire and Cabanillas, 2006) for implementation of individual agent. Agents can retrieve information and knowledge to perform tasks under control of rules or guidelines. Two types of rules are specified, one for clinical decision and another for administrative process control.

5 CONCLUSIONS

This paper has presented a three-layer architecture of an agent-based healthcare process management system. The agent-based cognitive approach is applied to facilitate dynamic and interactive processes in healthcare management. The treatment of primary open angle glaucoma is used as an example for demonstration. After the implementation of the prototype, we will evaluate the effectiveness of the approach in terms of support for clinical and administrative process management in healthcare environment. Relevant clinical and administrative staff will be invited to use this system and give feedback and evaluation on the system.

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REFERENCES

Bellifemine, F., Caire, G., and Greenwood, D., 2007. *Developing Multi-Agent Systems with JADE*, Chichester, England; Hoboken, NJ: John Wiley.

Caire, G. and Cabanillas, D., 2004. Jade Tutorial Application-defined content languages and ontologies, Manual, TILAB.

Hodapp, E.M.D., Parrish, R.G.M.D., and Anderson, D.G., 1993. *Clinical decision in glaucoma*, Mosby-Year Book, Inc.

Lenz, R. and Reichert, M., IT support for healthcare processes– premises, challenges, perspectives. *Data & Knowledge Engineering*, 61 (1)**,** 39-58, 2007.

O'Connor, M., Shankar, R., Tu, S., Nyulas, C., Das, A., and Musen, M., 2007. Efficiently Querying Relational Databases Using OWL and SWRL *The First International Conference on Web Reasoning and Rule Systems.* Innsbruck, Austria, Springer.

van der Aalst, W.M.P. and van Hee K.M., 2002. *Workflow Management: Models, Methods, and Systems*, MIT press, Cambridge, MA.

Wang, M. and Wang, H., 2006. From Process Logic to Business Logic - A Cognitive Approach to Business Process Management. *Information & Management*, 43 (2)**,** 179-193.

Wooldridge, M. and Jennings, N.R., 1999. Software Engineering with Agents: Pitfalls and Pratfalls, *IEEE Internet Computing*, *3*(3), 20-27.