A FRAMEWORK FOR DYNAMIC KNOWLEDGE ACQUISITION

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Keywords: Collaborative Work, Multi-agents, Medical diagnosis.

Abstract: This article proposes a conceptual model based on agents in medical workgroups for the resolution of clinical cases. Our objective is to provide a suitable conceptual framework for the dynamic acquisition of expert knowledge from different sources. This framework is sufficiently flexible to allow its transformation to the symbolic level that finally characterizes the implementation approach; it is a design model prior to implementation. We considered an interface design to be used for the integration and combination of different sources of expertise. The subject which interests us is the knowledge produced in the workgroup processes.

1 INTRODUCTION

There are many applications related to the workgroup such as decision-making, monitoring, transmission, planning, idea generation, problem resolution, resulting discussion, negotiation, conflict resolution, analysis and system design and collaborative group activities such as the preparation and distribution of documents, to mention just a few. This work style is illustrated by real-life applications, where their nature is clearly collaborative. Several of these applications imply various specialized fields, such as medical diagnosis. The field of medicine has become so vast that it is divided into several specialities and many medical cases are considered by group analysis. Among the various workgroup activities, complex-problem resolution is highlighted as being an increasingly important subject today.

Different information technologies which consider these group modalities have been developed in software engineering. Thus, we found a broader field entitled group support systems or electronic meeting systems which include other wide areas like Group Decision Support Systems (GDSS), Distributed Group Support Systems (DDSS), Computer Support Collaborative Work (CSCW), Groupware, where the common denominator of such technologies covers, but is not limited to, distributed facilities, computer hardware and software, audio and video technology, procedures, methodologies, facilitation, and applicable group data (Turban, 1995).

On the other hand, the evolution of the application domain in traditional Artificial Intelligence (AI) to cover other complex and heterogeneous fields such as aid to decision-making, form recognition and comprehension, process control, etc., shows the limits of traditional AI approaches. All this has contributed to the birth of a new discipline: Distributed Artificial Intelligence (DAI), which is interested in the intelligent behaviours (and their modelling) that are the outcome of cooperative activity between several agents. Nevertheless, the passage from individual behaviour to collective behaviour is not only considered as an extension but as an enrichment of AI, as new properties and new behaviours emerge from it. The purpose of DAI is to provide a remedy for the shortcomings of the traditional AI approach by proposing expertise distribution for an agent group capable of working and acting in a common environment, and solving possible conflicts. New concepts in AI have appeared, such as cooperation, action coordination, negotiation and emergence. Three fundamental research areas of DAI are multi-agent systems (MAS) (Weiss, 2000), distributed problem solving (DPS) and Parallel Artificial Intelligence (PAI).

2 THE PROBLEM

Everyday medical work (implying inter-consultation between specialists, case conferences, and hospital morning rounds) includes exchange and cognitive

Aguilera A. and Subero A. (2008).
A FRAMEWORK FOR DYNAMIC KNOWLEDGE ACQUISITION.
In *Proceedings of the International Conference on e-Business*, pages 58-63
DOI: 10.5220/0001913800580063

processes within groups. It is possible to observe different physicians (specialists and non-specialists) working together, at the same time or at the different time, on the same patient (clinical examination often requires the cooperation of several specialists). The contribution of these exchanges to solve complex problems is becoming more and more essential. These acts of collaboration are important for clinical decision-making concerning diagnosis and treatment both for students still in training and recently qualified physicians, without forgetting the continuous experience which helps to develop expert knowledge. There are several examples: cases of multi-system illnesses where physiopathology and the nature of origin of the illness make it necessary to examine the results of several diagnostic procedures; patients with chronic disorders such as diabetes mellitus, obstructive pulmonary illnesses, cardiological illnesses; or patients receiving palliative care at home.

On the whole, the most frequent scenarios where it is possible to observe this collaborative pattern are:

Inter-consultations. This is a process where a physician needs specialized consultation with several other physicians. There are two possibilities for this process: 1) between specialists with the same speciality (consultation between radiologists who study an image to decide on a diagnosis) and 2) between specialists with different specialties (an obstetrician who refers his/her patient to a cardiologist for a coronary problem).

Case Conferences and morning rounds. There are cases where it is possible to find several physicians (specialist physicians interconnected with general practitioners) exchanging information on several medical cases in order to make patient evaluations, to work on the publication of cases, etc. These are considered as staff meetings.

A clinical case illustrating this type of work is shown in figure 1 (A more detailed explication is found in (Quintero, 2003). In this case, we can observe the interaction between a generalist, a radiologist and a pathologist.

3 PROPOSITION

3.1 Architecture

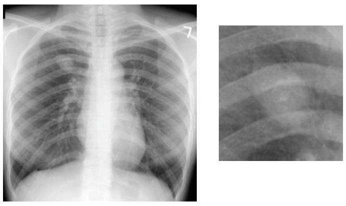
The problem follows a structure on three levels (Figure 2): the collaborator level or users (human agents), computer systems agents (software agents) and the data level (databases and knowledge bases). This architecture determines the structure on which the framework will be defined and permits us to clarify the semantic definition of the problem under study.

3.2 Methodology

Different methodologies for the development of knowledge-based systems (where knowledge acquisition and modelling play a leading role) have emerged during the past 15 years. We can mention in particular methodologies such as KADS (Schreiber, 1993), VITAL (Domingue, 1993), REFLECT (Reinders, 1991), (van Harmelen, 1992), ACKnowledge (van Heijst, 1992), CommonKADS (Schreiber, 2000) and KATEMES-MultiExp (Ladibi, 1995). KADS and VITAL focus on the development cycle of a knowledge-based system, REFLECT proposes theories and architectures for reflexive systems, ACKnowledge introduces directive models for knowledge modelling. CommonKADS offers methodology for knowledge-intensive system development and for knowledge management and KATEMES-MultiExp is a prototype tool for multi-expert knowledge acquisition.

The approach used is based on an extension of the KATEMES-MultiExp methodology. This method integrates a set of models for modelling multi-expertise and its objective is to help the knowledge engineer in the collecting and modelling phase of human behaviours in cooperative problem solving. These models are: agent, organization, cooperation, task and communication models (Aguilera, 2003b). We added a coordination model (Aguilera, 2003a) because originally KATEMES was designed for knowledge acquisition before system development and we considered the dynamic knowledge acquisition approach. One of the important features considered is the ability to extract expertise in a non-intrusive way. This minimizes biased behaviour by monitoring expert decision makers directly (through the information system) during their daily tasks, without changing anything about their choices or strategies. The approach is based on the concept of the agent, with the idea of modelling a group of experts via a community of agents in interaction. This gives us the additional advantage of multi-agent systems which provide a way to relax the constraints of centralized, planned, sequential control and to make systems that are decentralized, emergent and concurrent available. We are convinced that, the modularity of a multi-agent architecture facilitates knowledge acquisition and the parallel design of each expertise. In fact, the multi-agent systems are

Patient data
Age: 40 years old.
Sex: masculine
Context: He is a non-smoker and he does not present any obvious particular antecedents in his past medical history.
Symptoms: He went to his general practitioner with a non-productive cough of three months.
Physical Test: normal
Treatment: palliative treatment
Complementary Tests: laboratory and paraclinical tests (Postero-anterior chest x-ray)



Circumscribed 2-3 cm Nodule located in the right upper lobe of the lung with the presence of interior calcifications of non-specified type. Scanner recommended. Heart and rest of study without obvious modifications.

CAT Lung scanner: It indicates a 2 x 3 cm mass with non-epimacular aspect located in the right upper lobe of the lung with non-specified calcifications.
There is no affectation of Mediastinum lymphatic ganglia. There are no other masses in the thorax.

Pulmonary biopsy: macro and microscopic analysis of post-operative piece.

Diagnosis: ENDOBRONCHIAL HAMARTHOMA.
The patient leaves the hospital and considering the benign origin of the pathology, the doctor recommends an annual check up with his general practitioner.

Figure 1: A clinical case.

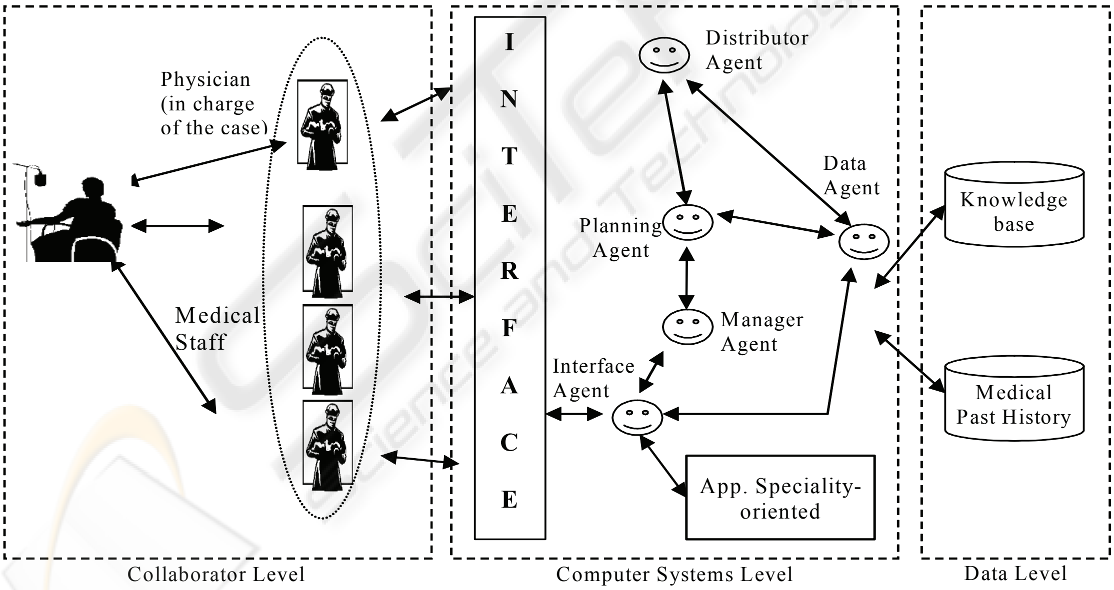


Figure 2: Problem Structure.

suitable for highly dynamic domains. They belong to the complex open systems category and make incremental application development possible.
Our choice is justified because agent modelling adapts well to the distributed nature of the problem, as well as, to the preliminary phases of the knowledge acquisition and to the development of collaborative activities between several experts.

3.3 The Framework

It is clear that the installation of a knowledge acquisition environment coming from multiple experts requires a multi-field approach which, at the same time, integrates social, cognitive and data-processing dimensions. It is for this reason that the objective of this model is to integrate social aspects coming from the human activities, cognitive aspects held in the databases and knowledge bases of the system, and the aspects related to computer systems. This proposal considers important aspects of multi-agent systems and software engineering.

We consider the importance of the conceptual model phase in the development of any technology, since it provides a good definition and a clear analysis of the problem treated. The model helps the knowledge engineer to consider the presence of all significant elements and their correct interrelations and it is also an instrument which enables him to exchange opinions with colleagues and experts, etc. The advantage of this framework is that it offers us a high level tool of abstraction. This tool enables us to discuss viewpoints with others and is therefore a facilitator for conceptual analysis. Additionally, this framework is a set of models that gives a wide vision including all actors, their interrelations, their organization, their communication mechanisms, and more.

The framework definition is given, simultaneously in the structuring and conceptualizing of each model in the extended KATEMES-multiexpert methodology. At the conceptual level we can define the following models:

- Agent model

This model enables us to identify and define all human and artificial individuals interacting and taking part in cooperative problem solving. These agents are (figure 2):

- The medical meeting agent: This is considered as a high level hierarchical agent. It is a set of agents and it is defined to identify the group of physicians. The communication protocol between agents follows human communication procedure based on personal conversations; that is, somebody intervenes and the others remain silent and listen, and when one person has finished, another intervenes and so on. The leadership position can be assumed by the doctor sitting opposite the patient (Physician in charge of the case).

- Medical speciality agents. They define a classification based on the different medical specialities, i.e., human agents such as radiologists, neurologists, pathologists and others. The knowledge of agents is heterogeneous. The agents divide the tasks amongst themselves and share data about the patient. Each one of these specialists can observe only one part of the “outside” (i.e., the patient).

- The patient: A human agent who as an active being takes part in his/her treatment. He/she requests medical appointments, takes part in his/her cure, asks for information. He/she makes it possible to establish the clinical context.

- The planning agent: An artificial agent which manages everything related to time in the system: assigns the tasks with a time context, checks the time of their activation, execution and ending. It returns the requests of task assignments if it has not received an opportune response. It centralizes information about task executions and their different states of development.

- The distributor agent: An artificial agent which locates the agents that will execute the tasks, according to their specialities and availability for executing them. For this, it takes into account the urgency of tasks required. It centralizes information about group members.

- The manager agent: An artificial agent which controls the requests for tasks. It sends and receives results.

- Interface agent: Artificial agent who controls the security accesses to systems and data. It adequately adapts the appropriate interface according to each user with his/her different levels. It centralizes general access information.

- The data agent: An artificial agent which manages data in the databases and knowledge bases. It manages metadata, user view definitions and authorizations to data access. It also controls anything related to data integrity and recovery mechanisms.

Subsequently and for reasons of brevity we will define only the radiologist agent. This is a human agent, an expert and a specialist belonging to the radiology department. He may be or not be subordinate according to his status. He is part of a community including radiologists or other colleagues of different specialities (general practitioners, pathologists, etc). All of these people rank equally and take part in the development of a diagnostic solution. This agent also has a hierarchical relationship with the department head.

With respect to inter-agent relationships, the radiologist could influence the reasoning line of an agent with another speciality, who requires his service for a diagnostic examination, or he could directly influence another radiologist who discusses a particular case with him. In the radiology department, software systems for image processing are frequently used. The execution of these systems can be initiated or stopped at any time by radiologists. Concerning cooperative relationships, the agent can assist another radiologist in the establishment of a diagnostic hypothesis or in other tasks. In the medical group context, his task does not interfere with other tasks but sometimes its accomplishment is important for the continuation of other tasks. Other inter-agent relationships can be established, but in order to simplicity, only those related to the example given (figure 1) will be mentioned.

- Expertise model

Knowledge based systems are founded on a separation between the knowledge necessary for problem solving (domain knowledge) and the reasoning mechanisms needed to exploit this knowledge (inferential process knowledge for problem solving). In the research field, this subject remains open and there is a great diversity of analyses and different viewpoints about it. This topic is related to reasoning mechanisms used by doctors in diagnostic problem solving. Many variables are considered: patient, doctor experience, general medical knowledge. The discussion of this theme is extended and goes beyond the domain of this article. We suggest readers refer to specialised literature (Torasso 2001, Long, 2001), in particular, we refer to (Park, 2003).

- Organisation model

In the architecture proposed (Figure 2), we find artificial and human agents. From this, we identify the medical group as a hierarchical structure with two levels; headed by the physician treating the patient, and then the rest of the doctors are considered to be collaborators. This structure can change by establishing as group leader another doctor in any other speciality.

It is also possible to observe other hierarchical structures, for example in a medical group within the same department (radiology department, pathology department, etc.), with the department head at the highest level.

Within a group of artificial agents, some have only coordination functions. A hierarchical structure is present and centralized in the manager agent. It is possible to observe delegation of tasks. For example, the manager agent requests that the planning agent specify the localization of a task and then the latter asks to the distributor agent which finally assigns the task.

- Cooperation model

The model presupposes the cooperative motivation of its participants. In the case of a medical group, the doctors can be assisted within the same speciality, when they request consultation at any step of the diagnostic process (doubts, confirmations, etc.). In different specialities, no one interferes directly with the others but their effective participation, in the total establishment of diagnosis, is decisive.

- Task model

To arrive at a diagnosis, doctors carry out several tasks. In particular we mention: hypothesis generation, selection and test of hypotheses and diagnostic conclusion. In the case of hypothesis generation, which is the example presented here, it is not clear if the same process is followed equally in every medical speciality. Undoubtedly, there are different contexts and expertise models can vary within the same speciality. However, it is not our objective to present a discussion of the diagnostic process.

- Communication model

There are several communication mechanisms between agents given by the type of their interrelations. For example, in the communication between human agents, there are communications based on spoken conversations, written conversations (chats) or by data (medical file). Between human and artificial agents, the communication is established by an interface agent. Among artificial agents, there are mechanisms based on message passing, and finally, between artificial agents and data, through a data agent. Communication modelling is described by inter-agent relationships via R-intervention relationships which do not contradict the organisational structures described. Some of them are shown in the definition of the radiologist agent.

- Coordination model

Coordination is supported by artificial agents: the manager, the planning and the distributor agent. They centralize everything related to the coordination tasks required. Coordination will also depend on the dynamics of the cases exposed, their characteristics, their emergency requirements, their resources and the interrelations established between the active agents..

Therefore services offered by this model depend on: the session context, the resources provided by participants and the social behaviour of participants (actions carried out by human agents) (Ossowski, 1999). The combination of these three elements creates the dynamics of coordination and the basic actions for this collaboration; the context fixes the limits of these dynamics.

3.4 System Design and Implementation

At implementation level, we design a multi-agent architecture based on the framework proposed. The different medical specialities are modelled well with a modular structure. The current project is progressing. So far, we have designed and implemented a groupware application that facilitates the management of clinical cases (Cárdenas, 2001) and a groupware application for radiological teleconsultations. The conceptual data model of our application uses an entity relationship model. At the moment, we are developing a workflow application for the coordination of medical diagnostic work.

4 CONCLUSIONS

In this article we defined an agent-based conceptual framework that integrates the social aspects of human activities, the cognitive aspects structured in databases and knowledge bases of the system, as well as, the computer system aspects which are present in the software applications and information technologies, in the medical diagnostic context. This approach is model-based; thus six models are defined: the agent model, the organization model, the cooperation model, the task model, the communication model and the coordination model. It is possible to instantiate these models for particular situations, for example, clinic and hospital frameworks. We have considered the extension of the metamodel proposed in (Ladibi, 1995), the annexing of the coordination model and we provided general templates for medical groupwork. The selection of the model-based method and the design of the model were directed towards the dynamic knowledge acquisition produced in collaborative medical interactions, which is the next the step in this research.

ACKNOWLEDGEMENTS

We are grateful to FONACIT, Venezuela, under Project No G-2005000278, which has sponsored this work.

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