AN AGENT BASED INFRASTRUCURE FOR FACILITATING EVIDENCE BASED MEDICINE

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Keywords: Multi-agent system, Evidence-based medicine

Abstract: Evidence-based medicine relies heavily on the timely dissemination of 'best evidence' to a wide audience of health practitioners (Atkins and Louw, 2000). However, finding, assimilating and using this information resource effectively can be difficult. In this paper we describe an infrastructure for facilitating evidence-based health care using Agora - a multi-agent system. This paper discusses a new application for AGORA, and also describes issues for disseminating such medical knowledge via an adaptive, intelligent, distributed, mobile information service. We describe how an agent based approach can deliver clinical cases and diagnosis information to clinicians at point of care tailored to her/his needs. This research in progress is particularly important for the facilitating flow of information in health care.

1 INTRODUCTION

We are developing a multi-agent system to assist with diagnosis decision making in health care using mobile devices. This paper discusses an application to AGORA, a multi-agent system, for disseminating such medical knowledge via an adaptive, intelligent, distributed, mobile information service. One of the aims of the project is to provide a novel solution for information service provision and selection for users of mobile devices. The application of mobile technology in this domain will involve the use of software assistant agents to proactively communicate availability of relevant clinical cases to clinicians. The software agent will also communicate with other software agents to make informed decisions based on specific patient medical results and documented medical research. This research in progress is particularly important for the facilitating flow of information in health care.

The overall research goal is to provide an 'intelligent' solution to medical services provision through the use of agent assistants. The project is to use agent technology to proactively communicate availability of relevant clinical cases to clinicians and provide personalised information tailored to meet the clinician's needs. We are particularly interested in promoting a way to disseminate clinical case reporting for diagnosis.

2 MOTIVATION

Previous research in the domain of evidence based medicine and multi-agent systems (MAS) have focused on information agents and appropriate information retrieval methods (Abasola and Gómez 2000). We propose extending this work by using agent technology to proactively communicate availability of relevant clinical cases to clinicians and provide personalised information tailored to meet the clinician's needs.

We are using an intelligent agents approach for disseminating medical research knowledge via an adaptive, intelligent, distributed, mobile information service. By adaptive we mean the ability of the service to adapt to the health professionals, service providers and communication context. By intelligent information services we understand ability of service to employ planning, reasoning and knowledge processing in order to satisfy the health professionals requirements. An important intelligent feature of the service is its pro-activity - ability to predict users' needs and to take initiative. The pro-activity of the service should be based on exploiting and (when it is not available) building the health professionals and/or service provider models by using machine learning and inductive inference techniques. By distributed information service we mean that components of the service system can be distributed

Sampson J. (2004).
AN AGENT BASED INFRASTRUCURE FOR FACILITATING EVIDENCE BASED MEDICINE.
In *Proceedings of the Sixth International Conference on Enterprise Information Systems*, pages 493-496
DOI: 10.5220/0002657804930496

across the network and that service can be composed from these components. By mobile information service we assume that both heath professionals and service providers can employ mobile devices such as mobile phones and PDAs for requesting/provision of an information service. Currently we are developing a prototype solution using Agora a multi-agent system infrastructure. Future research will be focused on the use of mobile devices to support the dissemination of the service. A multi-agent system infrastructure may include different levels and components, however currently we are focused on the cooperative work component in the infrastructure which we consider to be at MAS middleware level. An additional complicating factor is the use of mobile devices for communicating medical information to clinicians.

Due to the increasing number of mobile portable devices in use opportunities for the development of a wide range of mobile information services exists. Matskin and Tveit (2003) comment that the development of such technology as WAP (and other mobile technology) makes it possible to provide users of mobile phones with access to the Internet and services which earlier were available only via PCs connected to the Internet. The application of mobile technology in the healthcare domain will involve the use of software assistant agents to proactively communicate availability of relevant clinical cases, evidence-based research and patient data to clinicians. The software agent will communicate with other software agents to make informed decisions based on specific patient medical results and documented medical research. However Matskin and Tveit (2003) note that mobile devices have severe restrictions that may complicate practical use of information services. These restrictions are largely due to the limitations of wireless data networks compare to wired networks (less bandwidth, more latency, less connection stability, less predictability and less standardized protocols) and to the limitations of mobile handsets compared to personal computers (small screen size, complicated text input, limited memory, slow CPU and more constrained energy supply).

We envisage necessary requirements for the services are simplicity and expressiveness of the services. It is possible that some of the limitations will be relaxed in the future by development of hardware or telecommunication networks technology but at the moment we shall consider these impediments when implementing mobile services. Services should be personalized - they should take into account changing healthcare professional's preferences. Thirdly, services should be able to adopt both to changes in the healthcare professionals preferences and in the context of communication (Matskin and Tveit, 2003). In addition we will assume that as much as possible work for service customization and provision should be done off-line without direct participation of the user of the mobile device.

Each clinician should be able to present his or her case profile by telling the EBM assistant specific patient case information and define specific areas of expertise. The confidentiality of the patient will be adhered to through the means of agents who own the sensitive patient data, this information will not be released to other agents and is what we describe as secret knowledge. The application is to facilitate health care practice by providing relevant feedback information regarding diagnosis and treatment information based on similar cases via a mobile service. This technology may be useful for doctors treating patients where it is not suitable for patients to attend a clinic, in this situation a remote check, communication or diagnosis is essential. We foresee that it should be possible to create certain default profiles for specific types of health care professional and case types. Figure 1 depicts our high level concept from an individual perspective.

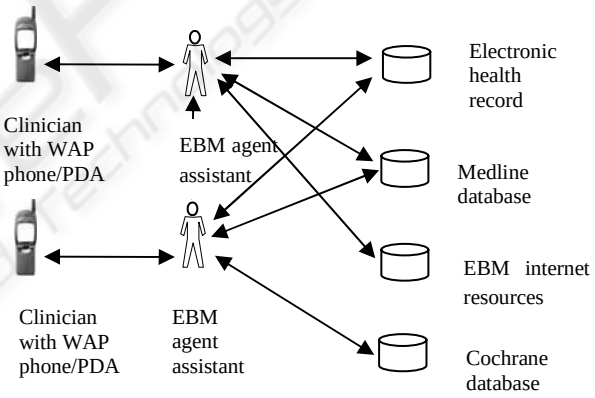

Figure 1: Agent-based solution for evidence-based healthcare

3 THE AGORA CONCEPT

We are using AGORA as a prototype environment for the development of an agent-based system for facilitating evidence-based health care. Matskin *et al.* (2001) have developed and successfully tested the AGORA system in other domains such as e-commerce. Our research is to modify the architecture for use in the health care domain, in particular for facilitating the dissemination of clinical cases to clinicians. While AGORA has been successfully used for virtual enterprises (Rao and Petersen 2003) we recognise that it is necessary to

modify the architecture and underlying knowledge base design to be appropriate for use in the healthcare domain.

The term 'Agora' originating in Greece, is the public forum and market place, where people gathered to discuss politics, news, exchange views etc. Similarly, agent Agoras are places where the agents arrive to communicate, negotiate, coordinate, collaborate and trade information and services (Matskin *et. al.* 2001). We have used the Agora metaphor in the development of a multi-agent system which consists of a set of interconnected Agoras and agents. Default agents are attached to an Agora while the other agents are registered at an Agora (Matskin *et. al.* 2001). The Agora system allows where possible agents to register and present activities. A matchmaker inside the agora compares the activities, and if two or more activities match, a negotiation agent will be started. This negotiation agent will manage the negotiation between these agents. The idea is that agents interested in some topic can find an Agora that operates in the specific domain, and then receive services and information through the Agora. The registered agents suggest that agents that want to "participate" in an Agora have to be registered first. The agent will then advertise themselves, and the Agora will help this agent to find other agents and Agoras that may help the agent to carry out tasks. Default agents are agents that are bound to the Agora to perform some services for the Agora. These agents may be performing services like negotiation, coordination, registration, or for example offering access to a database. It is possible for agents to be registered at several Agoras and that there could be interrelations between Agoras (Matskin *et. al.* 2001).

Agora has been developed using Java, and JATLite is used as a tool for communication (Matskin *et. al.* 2001). Prior research has found that it possible to run more than 70 agents concurrently on the JATLite router. KQML is used as the basic external communication language and protocol for exchanging information and knowledge. A separate communication format Message Wrapper has been defined inside the agents and Agoras. Between the internal format and the external KQML language there is a translator. We are now using this translator to use FIPA instead of KQML, by building a new FIPA translator.

3.1 Using AGORA for facilitating evidence-based heath care

The main advantage with the Agora approach is that the agents have rather simple implementations because of the gathering of specially designed services and functionality inside the Agoras. In such an application agents will represent the clinicians, the case events and the evidence based medicine service providers. In order to implement a virtual health care Agora we first identify participants of the cooperative work. We are interested in the roles specific agents will undertake.

- Clinician agent - represents the medical professional, at this point of time we only consider practitioners of medicine who undertake clinical work.
- Active case agent – represents a clinical case currently under care
- Completed case agent – represents published clinical case reports
- Case manager agent – a coordinator of cases and clinicians in a health care environment.
- Diagnosis negotiation assistant agent – matchmaking active case with other cases
- Cochrane library collaborator agent – manager of the agents representing specific health domains.

Cooperative points for agents work in the health care domain can be identified, as follows:

- Coordination of the health care activity
- Coordination of different clinician agents
- Coordination (information gathering) and diagnosis support between a case manager agent and the Cochrane library agents.

These cooperative points can be mapped into the following set of agoras: a clinician agora, a case agora, a diagnosis agora and a cochrane collaboration agora.

Agora represents both registered and default agents (refer Figure 2). Registered agents are either: coordination agents, negotiation agents or participant agents. The first two types of agents manage coordination and negotiation activities to be performed at the corresponding Agora. The participant agents represent participants of the cooperative activity. The default agents in Agora are the Agora manager, service and matchmaking agents. Each participant agent (for example case agent) presents offers and requests for information. Offered activity (OA) may be any activity the agent can perform by itself, for example in the heath care domain an offered activity could diagnosis information offered by the diagnosis assistant agent. Interrelations and connections among agents and Agoras are depicted at Figure 2. Lines between Agoras mean that agents from connected Agoras can be registered on both of them. Each Agora is shadowed as there is more than one Agora of each type. The coordination agents manage corresponding protocols.

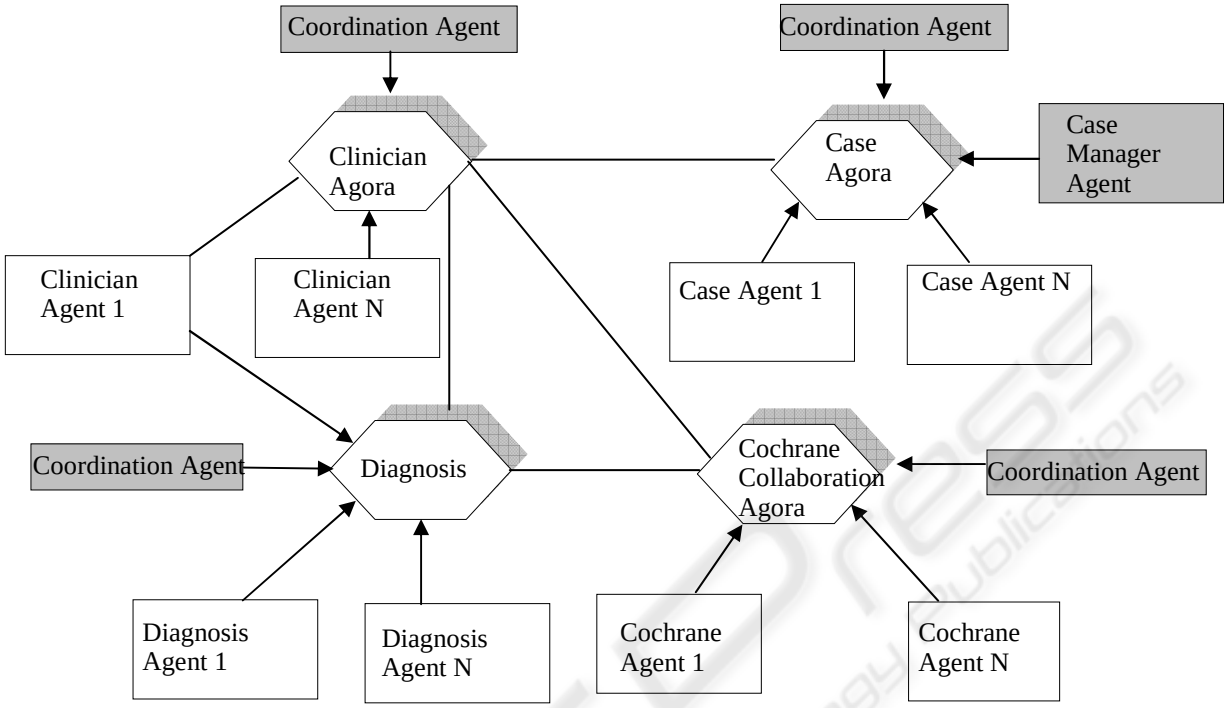

Figure 2: Virtual Health Care AGORA

Wanted activity (WA) could be any requested information from clinician agents regarding clinical cases. Agora allows direct matching of OA and WA; however we are currently overriding this default matchmaking using semantic matchmaking and ontological analysis. This is an important issue in clinical case matching, we are employing fuzzy matching techniques, where the matching procedure is not so precise or complete (80%/50%). Another important consideration is the composition of cases, we are determining the efficacy of service composition in this domain. Each of the agents in the Agora platform has the following modules: goal analyser, knowledge base, planner (in XML), scheduler, action creator and communication threads. We are currently working on defining the ontology for the knowledge base module of the case and diagnosis agents. The knowledge base module maintains storage, retrieval and querying knowledge.

CONCLUSION

The platform described in this paper was previously developed using the Agora concept for facilitating cooperative work. Our research is towards using Agora for facilitating the dissemination of medical knowledge and for assisting diagnosis in a clinical setting.

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