COMMUNICATION OF MEDICAL INFORMATION USING AGENTS

John McGrory, Frank Clarke
Dublin Institute of Technology, Dublin 8, Ireland

Jane Grimson
School of Computing, Trinity College Dublin, Dublin 2, Ireland

Peter Gaffney
Adelaide & Meath Hospital, Incorporating the National Children's Hospital (AMNCH), Tallaght, Dublin 24, Ireland

Keywords: HL7, *Open*EHR, CEN-ENV13606, agents, computer, guidelines and protocols.

Abstract: Agents are self-contained software entities which act faithfully and autonomously on behalf of a body of knowledge. They can operate in a standalone capacity, or as part of a social group collaborating and coordinating activities with other software agents. To access their knowledge, agents are interfaced with using message passing communication. The principle behind medical communications is to provide a means for exchanging information and knowledge from one computerised location to another, whilst preserving its true meaning and understanding between the listener and sender. Agent communication is similar to medical communications, but must provide an additional framework element to allow agents to interact at a social and operational level. Social aspects relate to agents collaborating on shared objectives, and operational aspects relate to coordination of tasks between the loosely coupled agents working as part of a group. Medical communications focus on data exchanges specific to the medical domain, while agent communication was designed for a much broader audience. Therefore, it is essential to verify if agent communications can support standard medical data exchanges. This paper investigates current forms of agent based communications and demonstrates they can support medical communication, yet retain their social and interaction information exchange functionality.

1 INTRODUCTION

An agent is a standalone, self-contained software application. It contains its own inference engine and is encoded using goals, plans and beliefs (Rao et al., 1995). The goals are used to describe its motivation, the plans are used to describe its intention (e.g. different types of workflow activities) and its beliefs are used to describe facts (e.g. weight, height or gender). Each plan and goal has some triggering condition using beliefs which must be satisfied before the plan or goal can be executed. The inference engine selects a goal and then chooses plans which can satisfy that goal whose triggering condition is also satisfied. Using this execution dynamic the agent reacts to known beliefs and events by selecting plans and goals. This permits the agent to be autonomous and self-contained. Using this principle the authors have developed an agent to act on behalf of a clinical and laboratory guideline. However, guidelines are rarely used in isolation and it is sometimes necessary for clinicians to review a number of these documents so a customised healthcare plan can be made for their specific patient. For example, if the patient was obese with early signs of renal failure. A guideline focusing on the obesity may indicate reducing the carbohydrates and increasing the protein to lower the weight. However, another guideline focusing on the renal failure would indicate reduce the protein in order to preserve the renal state of the patient. Technically

McGrory J., Clarke F., Grimson J. and Gaffney P. (2008).
COMMUNICATION OF MEDICAL INFORMATION USING AGENTS.
In *Proceedings of the First International Conference on Health Informatics*, pages 81-86

both guidelines are correct, but provide conflicting information affecting patient healthcare.

Applying the agency concept to guidelines, it was stated that an agent can be encoded with all the goals, plans and beliefs related to a particular guideline. Therefore, if the two guidelines referred to above where encoded into separate autonomous agents, they could communicate, work as a group and collaborate to provide a solution. Supporting knowledge from one guideline could be sent as a message to the other guideline. When this knowledge is received by the other it would update its beliefs (say proteins must be lowered) and this information changes the goals and plans that can be selected. This is because the goals and plans are selected in relation to the agent’s beliefs.

The principle aim of medical data communication is to provide a means for exchanging health information and knowledge from one computerised location to another in a complete and context rich format. Its goal is to preserve the true meaning and understanding of information when communicated to another application. To realise this different medical communication standards exist, but none contain any facility for communication to take place at a social or collaborative level.

The thrust of this paper is to illustrate software agent communications, particularly the Foundation for Intelligent Physical Agents (FIPA) message standard is capable of providing a context rich data transmission, similar to that offered by existing medical communication standards, and yet retain its agent social and interaction information exchange functionality. This would permit the agent communication approach to provide equivalent data exchanges as that provided through the medical communication standards, but yet allow the agent act as a socialite with a group of loosely coupled agents which can collaborate and coordinate to solve problems.

2 MESSAGE CONSTRUCTS

From a medical perspective there are three main standards used for constructing messages:

1. CEN-ENV13606-4:1999(CEN, 1999) (currently under revision prEN13606 :2004(E)),
2. HL7, Release 2,
3. *Open*EHR, Release 1,

In the current pre-standard documentation release of CEN prEN13606:2004 (only certain parts available at this time) there is a synergy between the three standards, and although not officially a standard yet, the CEN standard will be the focus of this paper.

From the agent perspective there are two main standards used for constructing agent messages:

1. FIPA Agent Communication Language (ACL) Message Structure.
2. Knowledge Query Manipulation Language (KQML)

The FIPA standard incorporates and extends many aspects of KQML, and has been the most widely used agent communication standard to date (Luck et al., 2004). Thus for the purposes of this paper the agent communication will focus on the FIPA standard.

Both the CEN medical and FIPA agent communication standards achieve their exchanges by message passing where they simultaneously integrate two types of information within a message (FIPA, 2002) (CEN, 1999):

1. Lower-level information(message payload)
2. Meta-information about the content of the message (message envelope).

The message payload is the structure of the message contents, such as XML, schema, or objects. The message envelope component relates to how the message is seen at a network level between the message sender and receiver. Both the message payload and envelope have different impacts on message passing communication. In the following subsections the function, use and meaning behind the message envelopes and payloads are discussed.

2.1 Message Payload

The CEN pre-standard prEN13606:2004 does not insist on a particular message payload type, and accepts formats such as an XML document, schema, or an object. All of these formats preserve the message data relationship model when communicating information from one system to another. XML permits developers to organise the structure and ordering of information in a document, whilst isolating it from the actual technical content. XML, in combination with other standards, makes it possible to define the content of a document separately from its formatting, making it easier to reuse content in other applications, or for other presentation environments. Most importantly XML provides a basic syntax used to share information between different kinds of computers, different applications, and different organisations without needing to pass through many layers of conversion. In this case the XML file itself is the message payload. The schema method is like a map or plan, where the information elements in the message are stored in a rigid format, and have a relationship to each other by virtue of their position in the schema. The receiving party is aware of the schema structure and can access the information slots to retrieve the required information. In this case the schema data file itself is the message payload. The Object method is where information is transmitted as a software object. The receiving party can interface with the object to retrieve the desired information. In this case the Object itself is the message payload. FIPA standard allows any Java object to be sent as part of a message payload. This object can be an XML, Schema or other type object which can be handled by the Java object class.

The primary difficulty in exchanging messages is to ensure the message being sent is understood and has the same meaning both by the sender and receiver. One simple natural language expression, such as "The woman is on the bus" can be used to illustrate the complexities associated with communications between different systems. This statement can be interpreted in several ways e.g., "the woman is travelling in the bus", or "the woman is painted onto the side of the bus", or "the woman is travelling on top of the bus". This ambiguity is in addition to the assumption that the observer (the listener) receiving the message knows what the "bus" object is (and this interpretation is the same as the sender) and "on" is a relationship description used when discussing the object "bus". The confusion associated with this bus example stems from an overlapping of ontologies. Language and ontologies are two interconnected components which are used to formalise the meaning of data, and preserve that meaning when sending and receiving messages (FIPA_a, 2002) (Noy et al., 2001). An ontology is a data model which represents language of a domain and is used to reason about these described objects and relationships between objects. Most people possess the capability to handle more than one ontology, such as a domestic and a work-related ontology. Therefore, different ontologies can co-exist in the one entity, but care must be made to ensure the message exchanges are filtered to match the ontology of the other party. Difficulties in communicating and sharing medical information between institutes, individuals or groups has generated a multitude of ontology and language implementations for example Galen (Rector et al., 2005) (Stuckenschmidt et al., 2004), Tambis (Baker et al., 1999), UMLS (Unified Medical Language System) (NLM, 2006), ONIONS (Gangemi et al., 1999), HL7 RIM (Beeler, 2001), GENE (Egana, 2005). These ontologies and language implementations specify various medical domains through an abstract conceptualised model of the real world environment. This demonstrates that no unique "one-stop-shop" ontology for the medical domain exists. The FIPA message structure recognises that in the real world different ontologies are present, and instead of forcing a single ontology, it allows many exist in the same environment and includes a framework to define, describe and manage them.

The FIPA ontology is composed of two parts, a vocabulary which describes the terminology of concepts used by agents in their realm of communication (e.g. dietitian or renal), and the classification of the relationships between these concepts, semantics and structures (FIPA_a, 2002). Exchanging messages using a specific ontology provides a richer contextual environment in which to share information between separate software entities.

In summary, a payload holds (or contains) the actual context rich medical information to be exchanged between two or more systems. The message is formed using specific ontologies to ensure the message is understood and has the same meaning between the sender and receiver. Both the medical CEN and agent FIPA standards allow similar types of message payloads to be transmitted. But for communications to work effectively it is vital that the message gets to the correct destination.

2.2 Message Envelope

To deliver a message payload to a specific destination it is necessary to wrap or encapsulate the payload using a message *envelope*. A message *envelope* consists of a number of key parameters which allows the message sender, receiver and content to be clearly identified during message transmission. Agents not only use messages for communicating information in a context rich form, but also for social and collaborative interaction so they transmit more envelope parameters, and messages in general. It is therefore imperative to compare the parameters used by medical and agent message standards to ensure the agent system can support them. This will identify what parameters (if any) would have to be added to the agent communication model in order to support medical transmissions.

By analysing parameters used by the ENV 13606-4:1999 (prEN13606:2004-Part 5: Exchange models was not available) medical communication standard and comparing them to the FIPA messaging standard it can be shown that six of the twelve CEN parameters have similar technical meanings. A list of these parameters is detailed in Table 1.

Table 1: CEN to FIPA message envelope parameters comparison.

Item	CEN ENV 13606-4:1999	FIPA
1	identification of message by originator	sender, conversation-id
2	EHCR source	sender
3	EHCR destination	receiver
4	EHCR message related agent	reply-to
5	language	language
6	message reference	conversation-id

The main purpose of the FIPA Agent Communication Language (ACL) messaging structure is to allow agents to communicate effectively when being utilised by a wide audience base, and were not designed specifically for a medical application. However, FIPA implementations are free to include customised user-defined message parameters other than the items specified within the standard itself. The semantics of these user-defined parameters is not defined by FIPA, and FIPA compliance does not require any particular interpretation of these parameters (FIPA, 2002). The prefix "X-" must be used for the names of these non-FIPA additional items. By reusing the overlapping parameters as detailed in Table 1, and adding the remaining six parameters using the prefix "X-", the fixed size of the message envelope is 65kbytes. The agent parameters now include the ontology parameter, so a message's ontology can be clearly identified, in addition to language before the message payload is accessed.

In summary, the FIPA messaging standard can be adapted with the addition of these user-defined parameters, to provide a similar message model to that detailed in ENV 13606-4:1999, and yet retain its agent communication functionality.

3 UTILISING AGENT COMMUNICATION

To compare the agent communications to an existing approach consider an example were four clinical guidelines are used together. The implementation chosen for illustration purposes was the evaluation of a set of Liver Function Tests to determine the cause of a chronic anaemia in patients.

One approach to managing the activities of the four guidelines is to decompose the guidelines into workflow activities and management rules. The management rules from each guideline are linked together centrally using an inference engine. This inference engine is constructed using rules that logically link the various workflow activities together. These management rules provide the motivation for a centralised inference engine to choose particular workflow activities depending on the patients known characteristics (e.g. weight, gender, height). The patient data is retrieved from the LIS using an XML message payload coupled with a standard CEN message envelope. As more guidelines are decomposed and added, the number of workflow activities and the size and complexity of the centralised inference engine increases. But all the decisions on choosing a particular workflow activity are performed centrally by the inference engine as no other separate modules exist in this system. The guidelines no longer exist as separate entities.

An alternative solution to capturing the knowledge of the four guidelines is to encode each as a separate autonomous agent, one agent for each guideline. This is achieved by encoding the guidelines beliefs, goals and plans together in the agent and using each agent's inference engine to interpret them. In this example there is no centralised management resource, therefore each agent must establish links to the other agents. To achieve this agents use message passing to share supportive information and coordinate activities. The patient data is retrieved from the LIS by each agent separately using an XML message payload coupled with a standard CEN message envelope. When an agent received a message from another guideline it altered (if necessary) its own execution based on this belief. If an agent wished to forward supporting information to the other agents it used message passing. Therefore, the only communication between the separate agent modules to coordinate activities together was via message passing, not direct linking as in the centralised solution. In this implementation no centralised resource was used to coordinate activities between the separate agents. After the agents completed deliberations the outcomes were compared to the documented case histories from which the evaluation data was taken. Although outcomes derived from the agent approach matched that provided by the case histories, it highlighted that the agent approach transmitted more messages than the former centralised approach. On average the group of four agents transmitted a total of 12 messages per second between them. This is because the separate agents relied solely on message passing in which to share information. During this evaluation it was also found that although the message envelope was a fixed size the message payload size could vary dramatically. This was because different types of information were being sent between the agents. Small messages where in the form of short supportive information comments. A longer message is where a more detailed packet of information was sent. Depending on the data being transmitted varying sizes of message payload ranging from 2kbytes to 360kbytes could occur. So how does this affect the computer system using the agents? If the agents, because they can be distributed were located on separate machines and a total of 12 messages was transmitted between them the network bandwidth would range from 8kbps for 2kbyte payloads, to 51kbps for the 360kbyte payloads (assuming the network had an efficiency of 10bits/byte). This is a substantial network overhead. However, this network overhead could be reduced if the agents with high message coupling where located on the same machine. The main reason for this message overhead is that the separate agents need to transmit data, social interaction data and collaboration data in order to operate. Whereas the centralised approach used fixed links between the workflow activities within the one application and so no network traffic was needed. However the agent approach was capable of providing distributed processing of the activities and only relationships between guidelines needing to collaborate needed to be established, where as the centralised approach needed to be run on a single machine.

4 CONCLUSIONS

This research demonstrates the agent communication approach offers the capability to transmit medical information, in an equivalent fashion to that provided by the existing medical communication standards, yet retains its agent social and interaction information exchange functionality. The FIPA ACL standard also allows for the ontology of a message to be identified so a richer form of data interaction can occur between agents. However, the concept of using the agents to represent guidelines highlighted that as the agents communicated data using messages, they also used messages to socialise and coordinate activities which could have a substantial impact on the network overhead. A summary of the difference between the two approaches is shown in Table 2.

Table 2: Summary Agent and centralised approaches.

Aspect	Agents	Centralised
Workflow activity links between guidelines.	Achieved using coordination message passing.	Achieved within the centralised inference engine.
Sharing of information.	Achieved using message passing.	Achieved by triggering rules within the inference engine.
Access to LIS.	Achieved using message passing. But each agent accesses it separately.	Achieved using message passing. But all required information accessed via one message.
Processing of guideline knowledge.	Distributed.	Centralised.
Guideline knowledge file size.	Small as each agent is self-contained.	Large as inference engine must cover all guidelines.
Adding, altering or deleting of guideline knowledge.	As each agent is independent there is no fixed link between them. So guidelines can be added, altered or deleted without impacting any other resources.	Adding, altering or deleting requires the links in the centralised inference engine to be modified. Therefore, all other resources affected.

REFERENCES

Baker P.G., Brass A., Bechhofer S., Goble C., Paton N., Stevens R., 1999. "*TAMBIS-Transparent Access to Multiple Bioinformatics Information Sources*", Scientific and Statistical Database Management, 1999. Eleventh International Conference on 28-30 July 1999 Page: 280.

Beeler G.W., 2001. *Reference Information Model (RIM) HL7 Version 3,* tutorial in two parts Part I & Part II accessed via http://www.hl7.org, 2001.

CEN/TC 251 Health Informatics, 1999. "*ENV13606-4:1999 Health informatics – Electronic Healthcare record communication - Part 4: messages for the exchange of information*, accessed via www.centc251.org.

Egana A., "*Ontology Design Patters for the Formalisation of Biological Ontologies*", Degree of Masters of Philosophy, University of Manchester, 2005 accessed via http://gong.man.ac.uk/docs/MPhilThesis.pdf

FIPA, 2002(Foundation for Intelligent Physical Agents). *FIPA Agent Message Transport Service Specification*, Document Number SC00067F, Dated 2002/12/03, accessed via http://www. fipa.org

FIPA_a, 2002(Foundation for Intelligent Physical Agents). "*FIPA Device Ontology Specification*", Document Number SC00091E, Dated 2002/12/03, accessed via http://www. fipa.org

Gangemi A., Pisanelli D.M., Steve G., 1999. "*An Overview of the ONIONS Project: Applying Ontologies to the Integration of Medical Terminologies*", Data and Knowledge Engineering, vol. 31, 1999, Pages 183-220, published by Elsevier.

Luck M., McBurney P., Preist C., 2004. *Agent Technology: Enabling Next Generation Computing: A Roadmap for Agent-Based Computing,* accessed via AgentLink web site http://www.agentlink.org/roadmap/ 2004 ISBN 0854 327886.

NLM 2006, National Library of Medicine USA *Unified Medical Language System* accessed via http://www.nlm.nih.gov/pubs/factsheets/umls.html, accessed October 2006.

Noy N.F., McGuinness D.L., 2001. *Ontology Development 101: A Guide to Creating Your First Ontology*. http://protege.stanford.edu/publications/ontology_development/ontology101.pdf. Stanford Knowledge Systems Laboratory Technical Report KSL-01-05, March 2001.

Rao A., Georgeff M., 1995. *BDI Agents: From Theory to Practice,* proceedings of the first international conference on multi agent systems (ICMMAS-95) San Francisco USA 1995.

Rector A., Roger J., 2005. *Ontological & Practical Issues in using a Description Logic to Represent Medical Concepts: Experience from GALEN*, School of Computer Science, The University of Manchester, Preprint Series, CSPP-35.

Stuckenschmidt H., van Harmelen F., Serafini L., Bouquet P., Giunchiglia F., 2004. *Using C-OWL for the Alignment and Merging of Medical Ontologies*, Proceedings of the First International Workshop on Formal Biomedical Knowledge Representation KRMed'04", Whistler, BC, Canada, 1 June 2004.