Multi-agent architecture for the Virtual Health Record

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Abstract

The Electronic Health Record is a central, unifying component in an eHealth infrastructure. In our paper we present a model for the EHR called Virtual Health Record[1] (VHCR) together with its services of discovery and cooperation implemented using software agents[2][3]. Having an open, decentralized architecture in mind we provide the VHCR the connection to a dynamic, non-deterministic world composed of different stakeholder working together in the care process. We also want to integrate seamlessly medical devices supporting the continuity of care in our eHealth solution, correctly including the readings for a constant monitoring of the patient`s health status[4]. The agent-oriented architecture and the interactions between components are presented.

Keywords:

ehealth, software agent, ehr, continuity of care

Introduction

The healthcare is the prevention, treatment, and management of illness and the preservation of mental and physical well being through the services offered by medical and third parties professionals.

An important step towards efficiency improvement and cost cutting in health care is the use of the Electronic Health Record (EHR), that is an individual patient's medical record in digital format. It enables a doctor to keep better track of his patients, to issue documents that can be interpreted by other doctors and other EHRs. EHR systems can reduce medical errors, increase physician efficiency and reduce costs, as well as promote standardization of care.

We are building a prototype of a patient centric software platform called VHCR (Virtual HealthCare Record) comprised of a longitudinal EHR and a population of software agents to support the continuity of care.

Goals

Our application deals with the following issues:

1) Information Integration: The system is tasked with interpreting and integrating information extracted from medical documents originated from various sources and updating a unique and coherent entity, the VHCR. The original documents are preserved in distributed repositories.
2) Semantic interoperability: The agents are not restricted to interpreting messages in a single standard but they are also tasked with translating from various standards with the help of a terminology conversion server.
3) Device integration: Already many medical device components are being integrated with the VHCR by interposing agents between the device and the VHCR to facilitate on-site medical measurements.., Data coming from these devices can be seamlessly integrated in the health record in real-time.
4) Longitudinal Record: The record of a citizen keeps track on the progress of the patient along a lifelong period of time. Healthcare is seen as a process extended in time.
5) Clinical workflows: A workflow agent monitors the treatment during an episode of care over a long period of time.
6) Patient awareness: Multiple human-interaction devices can be registered in the system to receive notifications.

VHCR

Virtual HealthCare Record (VHCR) is the central part of our application. VHCR is not a document repository, instead it is a healthcare service provider. It holds data extracted from medical documents in a finer grained model than the documental model permits. Even if the primary sources of information are most likely to be document-based it is more

convenient to store information in an object-relational data model. The reason for this is that we need a relational model to support efficient and complex queries. The medical document from where VHCR extracted its information to populate the data structure is not lost. Integration is done by analyzing the document in its medical context (Episode Of Care, Health Issue) and making the necessary updates in the record. In effect integration and interpretation transforms the information received from the PoS from a document based-model into the relational model we developed. Documenting the health status of a patient is done by using health issues. A health issue is a single health problem like asthma, a broken leg etc

A health issue has a life cycle of its own spanning across a time period. In this period we can have more episodes of care, for example a patient with asthma has this health issue all his life.

An episode of care is a workspace which logically groups relevant data from an instance of the treatment. This way a doctor can download from the VHCR only the information from the current episode. Also we use episodes of care for a finer grained access to information, the patient can give privacy rights using based on the association (<episode>,<role>).

Episodes of care can be active, suspended or closed at a moment in time. Closed episodes are archived for future reference.

An episode of care consists of more contacts. A contact is an encounter between a patient and a health care provider. Each contact has as an outcome a document, stored in a repository and interpreted by the VHCR.

During a contact the health care provider offers a number of services to the patient. These services include prescription of medicine, referrals for further analysis or specialized procedures. These care services can be atomic or can be grouped in a care plan, a workflow of services to be executed and monitored locally.

Results of medical analyses are also available in the health record. They can range from blood readings to x-ray images.

AGENTS

In the followings some agent types are introduced.

Specialized agent of the VHCR

VHCR exposes its services using a specialized agent that interacts with it. The “VHCR AGENT” is responsible for integrating data from other agents into the VHCR and also for answering queries regarding the patient’s health current status, history, and ongoing treatments. VHCR agent is the only agent aware of the internal structure of the health record.

Synthesis agent

Synthesis Agent is responsible with synthesizing specialized health summaries. In a scenario a patient is referred to perform a procedure in a private clinic. This clinic requires the medical situation of the patient and is able to process electronic documents sent in Continuity of Care Document[5] format , in Continuity of Care Record[6] format or in a proprietary format. In this case the agent will extract a summary in the required format. For translating data in an unknown format the agent interacts with the translation agent, described below.

Device Agents

Each medical device will be represented in the virtual space by an agent responsible for getting data from the device and sending it to the “VHCR AGENT”. The “device agent” can also be used to send configuration requests to the medical device. To install such an agent the medical device must be registered in the system, by using the patient portal. If the manufacturer of the device provides the software agent it will simply be downloaded and started in the agent container. If the manufacturer provides a non-agent software then an adaptor agent will have to be configured to work with the available software.

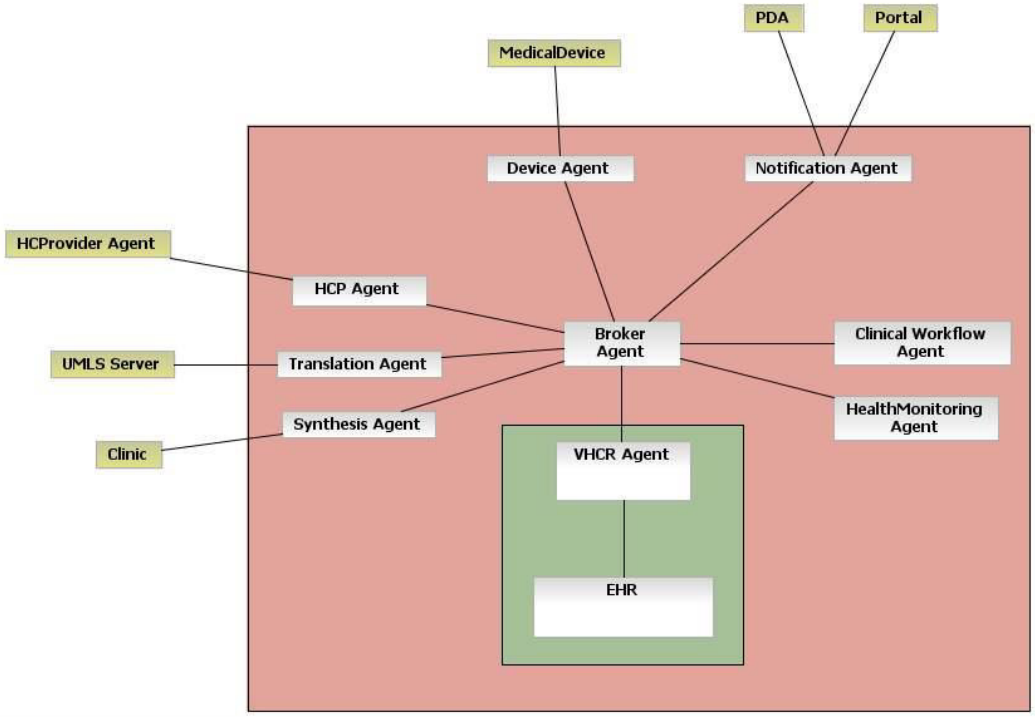


Figure 1 - Local agents interact with the world

Agents that interact with agents from general practitioners and clinics

Most medical data to be incorporated in the VHCR comes from patient encounters with healthcare providers. Healthcare providers will use different software applications that need to interact with VHCR either to receive data or to send medical documents for integration. To each such collaboration an agent will be assigned "HCP Agent" that will be responsible for receiving signed document, sending them to VHCR-incoming agents and forwarding queries to VHCR-outcoming agents.

Clinical workflow agents

Once the patient's health issue is found out, a health care provider can devise a care plan to be carried out by the subject of care and his/her care providers. The care plan is a workflow including activities that range from observations and future appointments to procedures and medication. The care plan is derived from a clinical guideline and tailored to the patient peculiarities. A patient can have more than one active care plan, saved in VHCR, corresponding to a specific health issue and episode of care. To each active care plan a workflow agent is assigned which monitors the realization of the care plan. For example it can send notifications before a scheduled procedure. When deriving the care plan, the health care professional can mark which activity realizations are required to be acknowledged. For example it is critical for the patient to take a medication once a day. When the medication is taken the patient marks this fact on his PDA or in the patient portal and the event is sent to the VHCR where it is extracted by the workflow agent. If the event is not received in the required interval, the workflow agent sends a notification.

Health monitoring agents

With the appearance of integrated medical measurement devices that provide a real-time monitoring of the life signs of a patient there is a need to interpret this data as soon as it is integrated in VHCR and raise an alarm if the measurements are off the scale. For this we introduce an "monitoring agent" which is an reactive agent with a set of rules <situation>.<action>. The agent is notified whenever a new measurement is added to VHCR. It extracts it and compares it to admissible limits. When the agent is first installed this limits are the default ones, based on the age, sex and health issues of the patient. However the healthcare professional can customize the admissible limits to others tailored to the patient treatment. The actions can be customized by the patient and consist in notification either of the patient or the general practitioner. An important issue here is the use of the monitoring agents in preventing the spread of epidemics. For example they can receive updates from national authorities when a new strain of flu appears, the symptoms being added to the

agent knowledge base. Suppose the symptoms consist of fever, coughing and headaches. When the patient measures his/her temperature the data is received by the agent which prompts the patient to answer a query regarding his condition. If the patient confirms the symptoms, he is informed he may be suffering from the flu and is invited to make an appointment to a health care provider.

Supporting agents

Broker agent

It acts as a registry for the agents supporting their discovery and communication. When a new agent is plugged in, it registers to the broker agent, publishing its services.

Agent lifecycle manager

It is responsible for creating new instances of agents, for activating and passivating agents when needed. It also acts as a garbage collector, removing unnecessary instances.

Agent`s ontology translation agent

In case our local agents communicate with agents and applications using a different medical terminology we need a set of mappings between different vocabularies to achieve semantic interoperability. This is done by creating and maintaining a registry of mappings, which falls under the responsibility of the agent`s ontology translation agent. Whenever an agent encounters an unknown term it queries the translation agent for a synonym. The translation agent either has the mapping in its knowledge base, either makes a query to an UMLS terminology server. The Unified Medical Language System (UMLS) is a compendium of many controlled vocabularies in the biomedical sciences. It provides a mapping structure among these vocabularies and thus allows one to translate among the various terminology systems; it may also be viewed as a comprehensive thesaurus and ontology of biomedical concepts[7].

VHCR Implementation

VHCR is implemented in a component-based architecture, using Enterprise JavaBeans 3.0[8].
We have chosen JADE[9] as a platform for our software agents. JADE offers a seamless integration of rules written in JESS[10], a Java implementation of the RETE algorithm. Currently we are evaluating the possibility of implementing our workflow agents in WADE, a JADE extension that allows agents to execute tasks defined according to the workflow metaphor.
The communication between the agents complies with FIPA specifications[11].

Conclusions and future work

Our VHCR project is in design phase. We are analyzing the infrastructure supporting VHCR, a middleware providing authentification, authorization and encryption services. An open topic is complying to ebXML standards, acquiring a better interoperability and also integrating health services in broader business processes.

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