Association for Information Systems
AIS Electronic Library (AISeL)

ECIS 2004 Proceedings

European Conference on Information Systems (ECIS)

2004

Adapt@Agent.Hospital - Agent Based Support of Clinical Processes

Christian Heine
University of Hohenheim, heine@uni-hohenheim.de

Stefan Kirn
University of Hohenheim, kirn@uni-hohenheim.de

ADAPT@AGENT.HOSPITAL – AGENT BASED SUPPORT OF CLINICAL PROCESSES

Heine, Christian, University of Hohenheim, Department of Information Systems II, Schwerzstraße 35, D-70599 Stuttgart, Germany.

Kirn, Stefan, University of Hohenheim, Department of Information Systems II, Schwerzstraße 35, D-70599 Stuttgart, Germany.

{heine|kirn}@uni-hohenheim.de

Abstract

In this paper we present a system for agent-based support of clinical processes. We describe the basic engineering concept, along with specific simulation and testing scenarios for agent-based software engineering. Another important focus is the integration of existing agent or healthcare standards like FIPA, DICOM and HL7. Objectives of our research activities in this project are: a substantial increase of the efficiency of hospital process management as well as the development of a specific goal oriented requirements engineering methodology. As most important challenges of the healthcare domain we have identified on the one hand individualized, patient oriented processes in diagnostics, therapy, nursing and administration and on the other hand extremely distributed decision processes and strong local (individual) autonomy with a high degree of situational dynamics. The example scenario on „clinical trials“ illustrates how the system shall support distributed clinical processes and how it interacts with other multiagent systems within the Agent.Hospital Framework and hospital information systems in the eHealth Lab introduced in this paper. The system development is part of the German Priority Research Program (SPP) 1083 “Intelligent Agents and their application in business scenarios”.

Keywords: healthcare standards, clinical processes, Agent.Hospital, multiagent systems, eHealth Lab

1 INTRODUCTION

Health service in Germany has grown over the last years into a more and more important field in economic studies. The budget of the German healthcare sector reached 218 Billion € in the year 2000 with a growth rate of 5-10 % per year. Thus, the current expense of health care is getting an important part of macroeconomics costs. It is expected that information technology plays a major role in reduction of expenses and stabilization of health care budgets. In the domain of hospital logistics complex and highly distributed systems are under research. These systems are designed to analyze the domain as well as to implement software systems esp. for management and control of information flows and business processes. The approaches to this domain are two-fold: on the one hand, simulation systems are used for analyzing the domain, planning and re-engineering of business processes. On the other hand, development of management and control systems for information flow and business processes is of interest. The raising importance of information systems is interlinked with specifics of the (German) healthcare domain like hard sectored distribution of professional groups, which complicates or particularly blocks the integration of processes and information systems.

Corresponding questions are examined since 2000 by the German Priority Research Program (SPP 1083). On this basis researchers from management science, information systems, and computer science are collaborating in order to advance the state of the art in intelligent software agents so that agent technologies for large systems in realistic business application scenarios can be developed and tested. The basic supposition of the SPP is that agent-based development and connection of decentralized information systems generates essential benefit by supporting interorganizational business processes and organizational flexibility. The examination of this hypothesis is supported by large distributed agent-based software systems.

As a part of the SPP 1083, we introduce in this paper first of all the essential questions and the research approach addressed by the ADAPT project (Heine et al. 2003), the developed system and its integration into the Agent.Hospital Framework (Kirn et al. 2003). We describe our participation in the research network Agentcities and corresponding HL7 (Health Level Seven)[1], DICOM (Digital Imaging and COmmunication in Medicine)[2] and FIPA (Foundation for Intelligent Physical Agents)[3] integration activities to realize large scaled agent-based distributed service networks for the healthcare domain. An example scenario on „clinical trials“ illustrates innovative simulation-based engineering processes provided by SeSAm (Shell for Simulated Agent systems) and our eHealth Lab. At the end of the paper we discuss the shortcomings and give an outlook on further research steps and implementation activities.

2 MOTIVATION & GOALS

The main objective of our research activities is to substantially increase the efficiency of hospital process management. As most important challenges of the healthcare domain we have identified on the one hand individualized, patient oriented processes in diagnostics, therapy, nursing, and administration and on the other hand extremely distributed decision processes and strong local (individual) autonomy with a high degree of situational dynamics. From our empirical studies we have derived some critical success factors to fit the objectives of our project:

- *completeness and topicality of information available to (human) actors*
- *knowledge about the actual patient status, timely triggers about its changes*
- *adequate representation of the variety and the dynamics of inter-/intra process interactions*

[1] http://www.hl7.org
[2] http://medical.nema.org/
[3] http://www.fipa.org

The project specific scientific objective of ADAPT in cooperation with our clinical partners, is the process and information flow optimization in participating oncology and radiation therapy departments. The experience gained should allow conclusions about the usability as well as the advantages of agent based software. Specific sub-goals of the project are

- *Improvement of distributed appointment scheduling*
- *Support for decisions about participation in clinical trials*
- *Operationalization of study protocols*

Appointment scheduling for treatment and examination tasks in hospitals is inherently distributed between various organizational units and there are a lot of interdependencies between the processes. This fact makes it very difficult to identify and explain effects of single-actions effects of and to optimize the process. Scheduling and negotiation strategies in the general praxis are mainly dominated by simple ad hoc solutions that can be optimized. Therefore simulation and analysis of real world scenarios and finding new more sophisticated processes is an important objective of the ADAPT project. Using clinical trials on chrono-modulated[4] medication, an agent-based system was designed and implemented in order to support the trial scheduling and coordination of patients, medical staff, and equipment. Induced by the complexity and regimentation of trial, much effort is needed for the coordination of all involved actors and equipment. Agent technology is used to handle the high level of environmental dynamics as well as the complex and restrictive requirements of clinical trials. Utilization and trial specific statements are supported by realistic simulation results.

Further objective of ADAPT is the implementation and application of established healthcare standards like HL7 or DICOM for interactions with hospital information systems (e.g. Radiology Information System (RIS) or Picture Archiving and Communication System (PACS)). Supporting the operational processes by coordinating the information flows (adapted to the individual medical pathway), the use of agent technology should result in a higher level of process efficiency.

3 AGENT.HOSPITAL FRAMEWORK

To evaluate the developed agent systems a complex and realistic evaluation scenario is needed. Therefore the working group „hospital logistics“ of the SPP 1083 including the ADAPT-Project developed an extensive and empirical funded model called Agent.Hospital (Kirn et al. 2003). This model is an agent-based testbed for numerous different and autonomously acting healthcare players. Agent.Hospital consists of detailed partial healthcare models and different kinds of service agents and agent-based platforms. The Agent.Hospital testbed supports evaluation of modeling methods, the examination of configuration problems as well as the examination of agent-based negotiation strategies and coordination algorithms in healthcare scenarios.

The involved research groups and application partners offer a wide spectrum of relevant clinical process models. Relevant organizational structures, processes and necessary data models were analyzed, formalized and modeled at several hospitals. On the conceptual level Agent.Hospital consists of partial models, process patterns, gateway specifications and shared ontologies. The resulting framework is an overall conceptual scenario based on the integrated project specific partial models.

[4] Chronomodulation has been an active field of medical investigation over the past 10 years, since the discovery of hormonal, immunologic and hematologic rhythms (circadian rhythms) in experimental animals and in human beings.

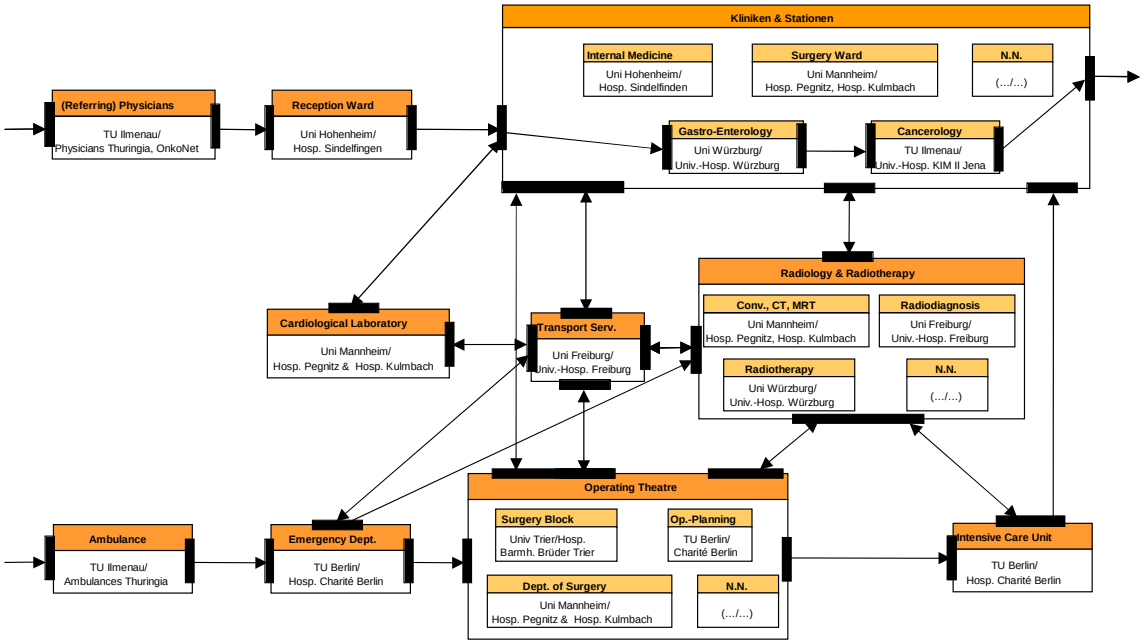

Figure 1. Application diagram of the Agent.Hospital framework with several selected supply chains.

Several clinics, departments and wards are defined in Agent.Hospital as service provider and consumer units. In the following the offered and requested services are referred to as services. For a technical interaction between the service providing and consuming units there is a need to use well defined interfaces based on existing agent communication languages, interaction protocols, content language and on common ontologies. Currently, the following overall supply chains shown in Figure 1 are implemented: clinical trials and radio therapeutics (ADAPT), rescue patient (AGIL), lung cancer treatment (ASAinlog), angina pectoris (MedPAge), gallstone therapy, surgery processes (Policy Agents), radiological service processes (EMIKA). More details and references to these projects are provided on the RealAgentS platform[5].

Important for the development of Agent.Hospital was the use of existing and established standards. In agent research the „Foundation for Intelligent Physical Agents“ FIPA plays the leading role. During the last years, the FIPA organization has concluded and proposed primarily standards for the design of agent platforms as well as standards for communication and interaction (Willmott et al. 2003). To be able to integrate the different agent systems made it necessary to develop a common ontology OntHoS (Becker et al. 2003) for interactions among the representing gateway agents.

Intelligent software agents in application have to be integrated in an existing (often proprietary) information system infrastructure. Therefore one of the objectives of ADAPT is the implementation, evaluation and documentation of agent-based services for integration of healthcare standards like HL7 and DICOM to be able to communicate and interact with hospital information systems. In this context we initiated cooperation with the German Association of Information System Producers in Healthcare (VHitG), to use, implement and if necessary extend specifications of interfaces between specialized applications (radiology information systems, practice systems, patient record, etc.) and agent-based systems. Agent.Hospital is realized as a part of Agentcities. Therefore several Agentcities platforms have been set up in five German cities. They are connected by a central directory service

[5] http://www.realagents.org

Agent.HospitalDF[6] (AHDF), which registers all participating service agents. In a distributed system like Agent.Hospital we cannot guarantee the availability of remote service hosts. Network problems and system crashes may affect service availability and we cannot presume that agents usually deregister themselves, before going offline. Damaged directories can negatively affect the remaining agents in the network. Thus the AHDF actively monitors the service agents sending periodic control messages. If these control messages do not reach the agent (for instance the Agent.Hospital platform is temporarily down), it is considered deregistered and tries to reregister through searching for and registering on a new or the same AHDF. Our ADAPT project as a part of Agent.Hospital is represented with agent platforms in Würzburg and Stuttgart-Hohenheim. Detailed descriptions about Agent.Hospital can be found in (Kirn et al. 2003).

4 TECHNICAL BASE

The agent-based simulation system called SeSAm is the technical base of the ADAPT project (Klügl et al. 2003). It is an integrated environment for modeling and simulating multiagent systems and one, which provides powerful modeling functions for easy construction of complex models and to enable domain-experts to create simulation models without programming. SeSAm provides a generic environment for modeling and experimenting with agent-based simulation and application. It allows visual modeling of agents and their environment respecting their properties, abilities and behavior. So it primarily addresses not programmers but domain experts to create simulation models. Different agent classes can be created and their properties and abilities can be defined by adding agent specific attributes and modular features.

The set of features can be easily extended and there is already a useful set available like for example “movement”, “evolution” and “scheduling”. By using these features and the basic set of primitive actions and functions the behavior of the agent can be described. Basic representations of the agents’ behavior are UML-activity diagrams (see Figure 2). They are easily understandable and a common well-known notation. Activity diagrams consist of activities and transition rules. The activities can be seen as states containing a series of actions, which are executed until an exit rule activates the next activity. Recent time several additional features to support handling more complex models like healthcare scenarios are integrated in the environment (Oechslein et al. 2002). So among various other features the environment allows hierarchical modeling at the level of functional description as well as on the level of behavioral description.

[6] http://www-i4.informatik.rwth-aachen.de/agentcities/RWTH_Agentcities_Web_files/hospital.html

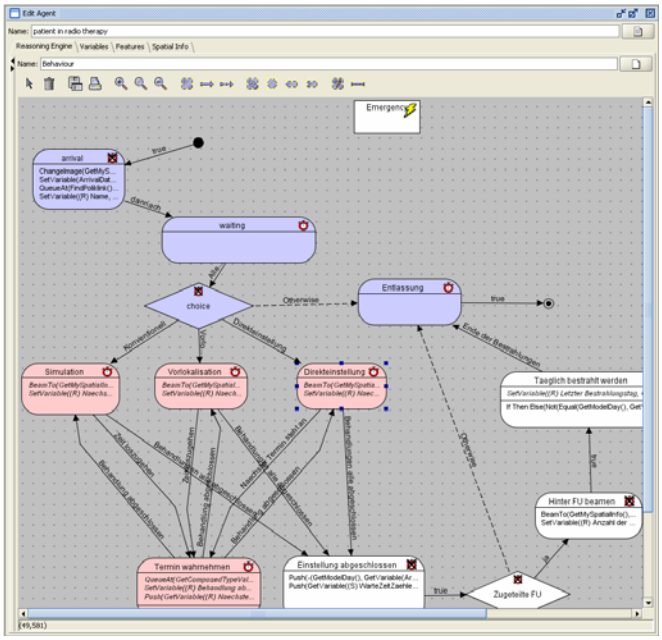

Figure 2. SeSAm - Visual agent behaviour modeling and simulation

Basic function primitives can be composed into more complex user defined primitives and parts of the activity graph can be melted together to compound activities. To simplify testing and finding errors in the model it is possible to create rules for invariant states, similar to assertions in modern programming languages. We developed and integrated a plug-in concept for additional SeSAm features, like database connectivity, FIPA support or ontology support. The new plug-ins provide FIPA-compliant communication primitives[7] or a possibility to import ontologies[8] modeled with the ontology tool Protegé2000[9]. After modeling the agent classes, simulation situations can be created on a two-dimensional map. For simulation of a scenario this model representation is compiled and can be run directly from within the environment. During simulation is possible to watch the animated map, pause and resume the simulation and to control agent's states.

Agent-based applications are part of an environment containing real world agents like users and other systems (possibly agent systems). In agent software development isolated tests are usually very difficult, instead tests have to be made under the conditions of this environment. As mentioned above, our idea was to extend SeSAm in a way that it can be used as a testbed for agent-based software without re-modeling the agent for interacting with the simulated environment. Then, creating models of the global system becomes rather intuitive. Figure 3 shows a sketch of this approach.

[7] plug-in with new primitives and data types that allow to connect the simulated agents to agents on other FIPA compliant platforms, like e.g. Jade

[8] this plug-in allows the user to select protegé ontology-files and import knowledge representation as user data structures

[9] http://protege.stanford.edu/index.html

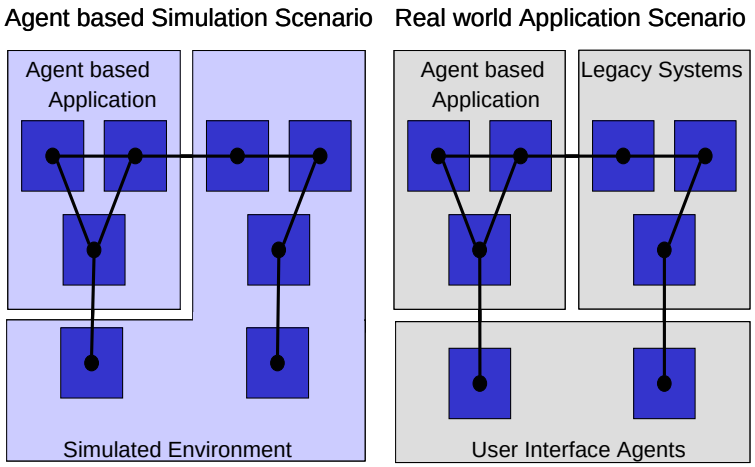

Figure 3. agent systems in a simulated environment vs. application in real world

An agent-based application is integrated in an environment consisting of additional information systems and users that can also be seen as agents. All agents from the real-world environment are replaced by simulated agents in SeSAm. The level of detail of the simulation is depending on the requirements of the agent system. Due to the representation of the real-world in the simulated testbed the developed components can be tested both, under realistic as well as under extreme conditions. This usually cannot be done in the real world for reasons of security and costs. Especially in the healthcare domain is practical testing of prototypical software dangerous. That's why we have the objective to realize an eHealth Lab for testing, evaluation and application of agent based systems in real world settings.

5 EHEALTH LAB APPLICATION TESTING AND EVALUATION

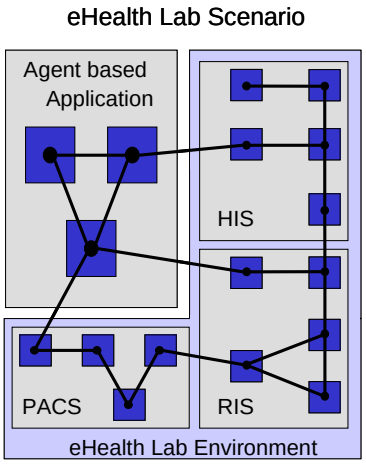

Figure 4. eHealth Lab scenario for application evaluation

The eHealth Lab is a project initiated in August 2003 at the University of Stuttgart-Hohenheim by Prof. Stefan Kirn. The project addresses the vision of "Seamless Healthcare". Typical software systems of the healthcare domain like HIS, RIS and PACS will be installed and different studies about

the interoperability of these systems will be undertaken. Seamless healthcare refers in that context to the provision of continuous vertically and horizontally integrated holistic care to patients through the contribution, co-ordination and collaboration of all healthcare service providers and carers in the healthcare domain. Such seamless healthcare depends crucially on the ability to share information efficiently between healthcare service providers. Essential is that everyone involved in these processes has access to all the relevant information. These developments are taking place against a background of increasing computerization throughout the healthcare domain, which has resulted in a diversity of heterogeneous, autonomous information systems all containing patient-related health data.

Seamless Integration of Healthcare Processes in the ADAPT Project is primary related to standardized image management and communication in hospitals and thereby uses the eHealth Lab infrastructure to test and evaluate agent based applications after they have been tested in the virtual environment simulation of SeSAm. Figure 4 shows the conceptual integration and interoperation of these systems.

The Agent.Hospital framework described in chapter 3 enables/facilitates in this context communication among different healthcare departments. Agent based DICOM and HL7 components enable interoperability of agent-based applications and hospital information systems as interface points and exhibit active behavior as message acceptors. Each participating multiagent system is with less effort (e.g. using common HL7 ontology) able to use the functionality of HL7 or DICOM modules to send specific messages, receive acknowledgements or view, process and send DICOM images of an image archive using DICOM protocols. First prototypes of the HL7 and DICOM modules are designed as FIPA compliant agents to handle examination orders, schedule requests or receipt of results, also in case of unavailability of necessary personnel (e.g. radiologists).

6 CLINICAL TRIAL SCENARIO

A special and expensive field in healthcare is the medical treatment of cancer. Clinical trials are carefully controlled studies in which oncology experts evaluate better ways to treat, prevent, or diagnose cancer. Really important is the increasing number of patients who are enrolled in clinical trials, as they represent an opportunity for patients with cancer to receive the best possible care.

Clinical trials are also extremely valuable also because they answer important questions that will help to continually improve cancer care and decrease the risk of cancer development. Before a new therapy or medical treatment can be put into daily clinical practice, a lot of trials have to be run. Clinical trials are detailed plans for medical treatment. For example a clinical trial protocol can describe at which point of time, in which quantum, and in which manner medications or therapies have to be executed. But clinical trials are not performed in linearity; instead their concrete structures depend on particular patient constitutions, laboratory results, etc. Clinical trials can be described by graphs, each node representing a particular state of a particular study.

Typical sample sizes for clinical trials require about 150 to 200 patients which makes it necessary in general that several hospitals cooperate in performing such trials (multi-centric trials). Figure 5 describes an exemplified process part of the integrated clinical trial scenario[10]. The simulation according to the process description is directed by SeSAm and utilizes several agent-based services provided by the SPP 1083. At the beginning of a clinical trial various tasks for diagnosis and treatment have to be coordinated and scheduled resources have to be assigned and if necessary informed. Figure 7 shows an example with CT- (computer tomography) and MRT- (magneto-resonance-tomography) examinations as well as execution of a surgery. As a first step, the suitability of the patient for the clinical study will be checked (age, gender, blood count etc.). If the patient fulfils the preconditions for the trial, then a MRT examination may be necessary. Planning of this examination means that different

[10] The description of the process is similar to the extended event-driven process chains (eEPC). The strict bipartite change from events and functions is repealed to simplify the description of the processes.

service agents try to negotiate mandatory appointments (see exemplary the gateways 2.5.3.1/2.5.3.2 in Figure 5).

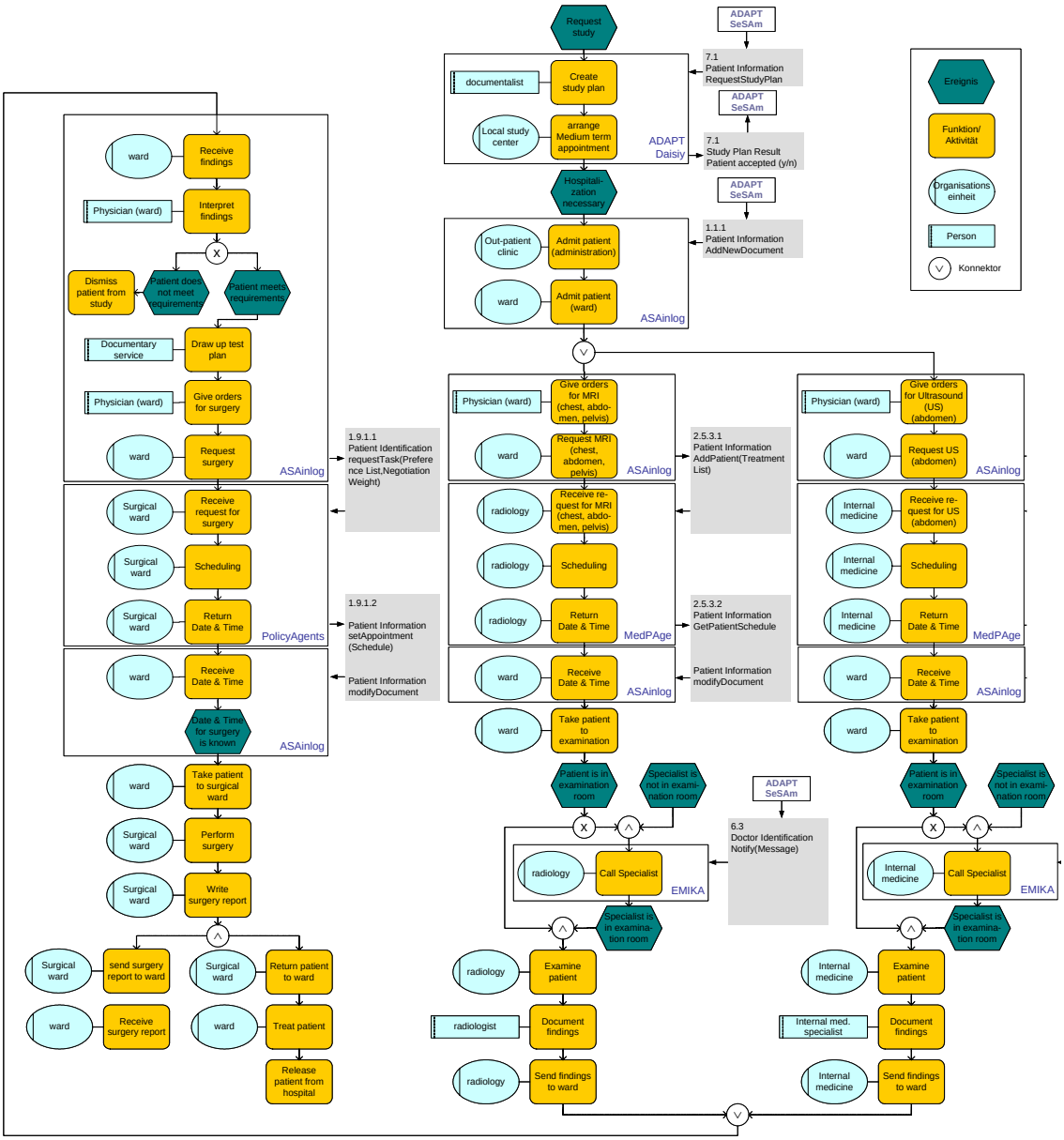

Figure 5. Exemplary part of the clinical trial scenario with interactions between different multiagent or hospital information systems.

But these agent-based negotiations are constraint by the existing timetable of the responsible hospital information system. To interact with this information system (precondition is HL7 compliance) the HL7 agent generates specific “HL7 Schedule Messages” like SRM (Schedule Request Message). The following Figure 6 shows exemplary the HL7 Schedule Request Message structure.

```
SRM^S01-S11^SRM_S01      Schedule Request Message
MSH                      Message Header
ARQ                      Appointment Request Information
[ APR ]                  Appointment Preferences
[ { NTE } ]              Notes and Comments
[ { PID                  Patient Identification
    [ PV1 ]              Patient Visit
    [ PV2 ]              Patient Visit - Additional Info
    [ { OBX } ]          Observation/Result
    [ { DG1 } ]          Diagnosis
  }
]
{ RGS                    Resource Group Segment
  [ { AIS                Appointment Information - Service
      [ APR ]            Appointment Preferences
      [ { NTE } ]        Notes and Comments
    }
  ]
  [ { AIG                Appointment Information - General Resource
      [ APR ]            Appointment Preferences
      [ { NTE } ]        Notes and Comments
    }
  ]
  [ { AIL                Appointment Information - Location Resource
      [ APR ]            Appointment Preferences
      [ { NTE } ]        Notes and Comments
    }
  ]
  [ { AIP                Appointment Information - Personnel Resource
      [ APR ]            Appointment Preferences
      [ { NTE } ]        Notes and Comments
    }
  ]
}
```

Figure 6. HL7 Schedule Request Message structure (SRM) of the clinical trial scenario

According to the message structure of Figure 6 the responsible HL7 Agent is able to receive, edit, process and send such HL7 messages to standard compliant hospital information systems (detailed tests within the eHealth Lab infrastructure with different HIS have to be done). The agents communicate FIPA conform and code the HL7 as well as the DICOM Messages as content into the FIPA-ACL messages (Agent Communication Language).

A Screenshot of the HL7 Message Agent interface is depicted in Figure 7. Relevant message segments and fields can be edited by the user and sent to the next responsible agent or hospital information system.

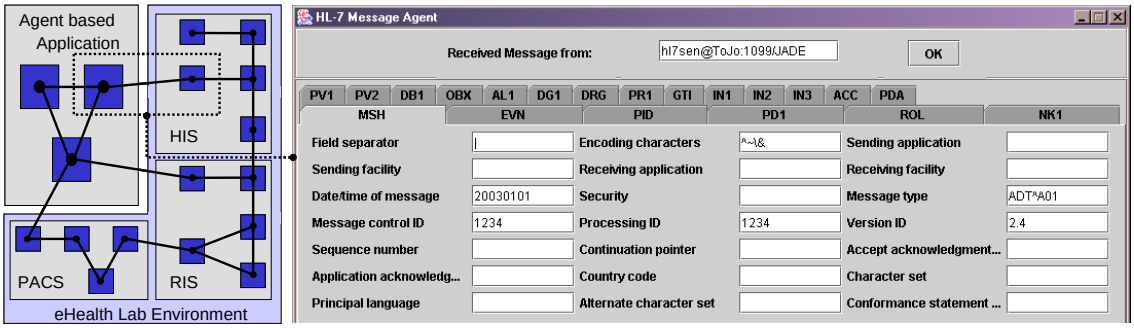

Figure 7. HL7 Message Agent for interactions with HL7-compliant HIS

After the MRT examination several HL7 messages have to be sent in our scenario. But the transfer of radiological image data is not supported by HL7. The transfer of image data for instance from the MRT modality to viewing workstations, digital archives or a remote radiologist for a second opinion is

supported by the DICOM standard[11]. The following interaction diagram (Figure 8) shows a simplified process of the system interactions within Agent.Hospital. Here are depicted just the essential steps. Interactions for error handling are not included (e.g. not-understood, refuse, failure).

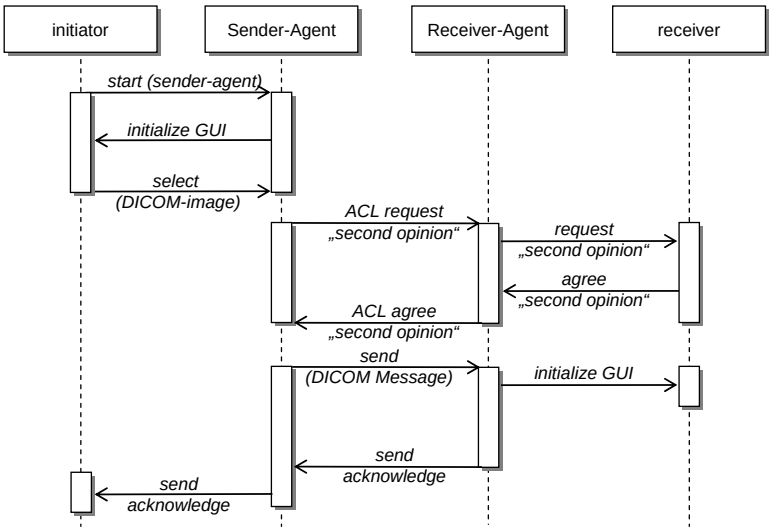

Figure 8. *” second opinion” in the clinical trial scenario with agent-based DICOM image transfer.*

The Screenshot of our DICOM Message Agent interface shows first viewing and editing (if allowed) capabilities (Figure 9). The DICOM image data with all header information can be sent by the agent to the next responsible agent or archiving system.

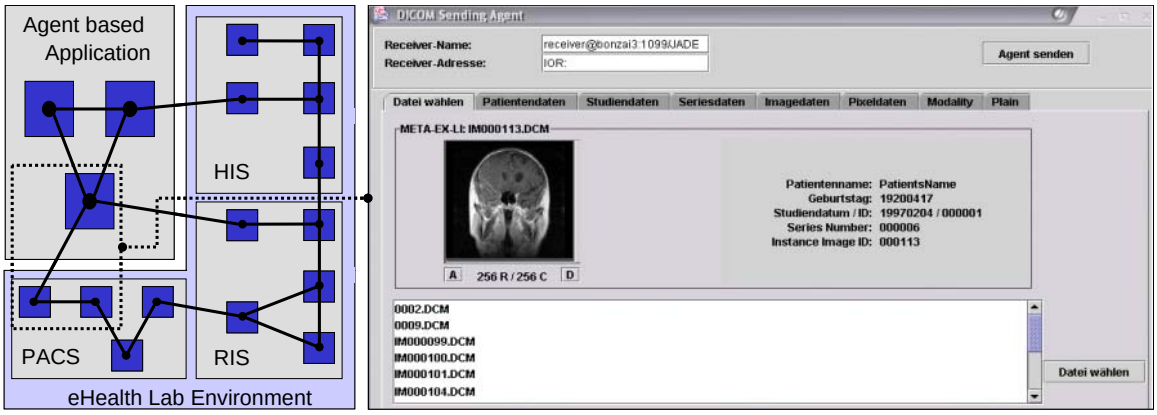

Figure 9. *DICOM Message Agent for interaction with DICOM-compliant PACS/RIS etc.*

All these interactions are basically implemented and tested according to the briefly described engineering process at first in a simulated environment provided by SeSAm and at the next step with real hospital information systems in the eHealth Lab in a secure laboratory environment.

Measures of the query response time made on the described Agent.Hospital DF infrastructure are shown in two diagrams of. The measures represented in the left diagram are made at the LAN of the

[11] Basic assumption is that all systems are DICOM compliant with specific “DICOM Conformance Statements”. These Conformance Statements specify supported parts of the standard.

University of Aachen and the measures in the right diagram between a host at the University of Aachen and a client at the University of Ilmenau[12].

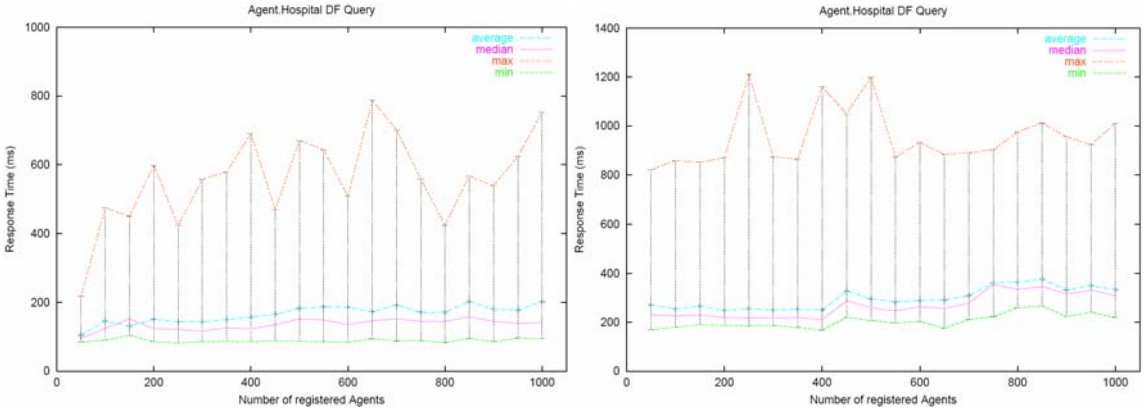

Figure 10. Response Time of the Agent.Hospital DF at the University of Aachen and Ilmenau

The query response time was measured 50 times for 20 different configurations, while in each configuration the number of agents was incremented by 50 agents. Interesting parameters of the measures made are maximum, minimum, average and median. Usually the average value can be used as a point of reference of future queries duration but it is often falsified by single very high response time peaks in comparison with the bulk of response times. Therefore the median value was also computed and is shown in both diagrams. In the local environment (Aachen) the median and the average value of the measured response times are less than 200 ms and in the distributed environment (Ilmenau) less than 400 ms. We have to consider this values for query intensive agent applications dealing with time planning, scheduling or resource allocations. Further the maximum values should be considered for real time applications dealing with hard time constraints.

7 SUMMARY & CONCLUSION

This paper described the conceptual design and the essential system components of Agent.Hospital, an open agent based (software) framework for highly distributed applications in healthcare. Agent.Hospital arose from the projects of the priority research program „Intelligent Agents and economic application scenarios". It serves to test and develop basic concepts and methodologies of the agent technology. It allows just making tests in laboratory conditions but as well in appropriate big and complex scenarios and under conditions that are close to conditions of real applications in health care (eHealth Lab).

FIPA, HL7 and DICOM compliance and consequent use of common ontologies facilitates this interoperation and enables the development of agent systems. We briefly described our development process from the modeling of process models (eEPC) and the construction of the simulation models with SeSAm over the laboratory environment like the eHealth Lab to an existing hospital information system infrastructure.

Our next development step provides import functionality for organizational charts, shift plans, eEPC-models etc. created with the ARIS toolset[13] based on an AML[14]/XML-parser plug-in into SeSAm (see

[12] The authors moved in the last months from the University of Ilmenau to the University of Hohenheim.
[13] http://www.ids-scheer.de/english/index.php
[14] AML – ARIS Markup Language

also IDS Scheer AG 2003). This plug-in is currently under development but still leads to raw SeSAm models, which can be refined to executable models.

The development of systems in the context of the SPP 1083 has come at all to a pretty pass. There are already powerful systems which showing the possibilities of the agent based approach. But indeed we still have to show the real practical use in a hospital. The main and ultimate objective is to bring agent systems to application. The results of the simulation and the systems developed should be practically used in management and control. We are now at the point, where we have to produce detailed evaluation results (see Figure 10) also in comparison to other conventional software systems. Beside this we share the opinion that the agent technology is able to handle the high level of environmental dynamics as well as the complex and restrictive requirements of clinical processes.

References

Becker, M.; Heine, C.; Herrler, R.; Krempels, K.-H. (2003). OntHoS - an Ontology for Hospital Scenarios. In: Applications of Software Agent Technology in the Health Care Domain (Moreno, A.; Nealon, J. Eds.). Whitestein Series in Software Agent Technologies (WSSAT), Birkhäuser Publisher Basel, pp. 87-103.

Haddawy, P.; Hanks, S. (1993). Utility Models for Goal-Directed Decision-Theoretic Planners. Technical Report 93-06-04, Department of Computer Science and Engineering, Seattle, USA.

Heine, C.; Herrler, R.; Petsch. M.; Anhalt, C. (2003). ADAPT - Adaptive Multi Agent Process Planning & Coordination of Clinical Trials. In: AMCIS 2003 Proceedings, Tampa/Florida (Best Paper Award).

Herrler, R.; Heine, C.; Klügl, F. (2002). Appointment Scheduling Among Agents: A Case Study In Designing Suitable Interaction Protocols. In: AMCIS 2002 Proceedings Dallas, pp. 1456-1463.

IDS Scheer AG (2003). XML Export and Import - ARIS 6 Interface Description. Saarbrücken. ftp://ftp.ids-scheer.de/pub/ARIS/HELPDESK/EXPORT/ARIS62/en_xmlexp62.pdf, [2003-02-04].

Kirn, St.; Heine, C.; Herrler, R.; Krempels, K.-H (2003). Agent.Hospital – agent-based open framework for clinical applications. In: Twelfth IEEE International Workshops on Enabling Technologies: Infrastructure for Collaborative Enterprises (Kotsis, G.; Reddy, S. Eds.). CS Press, Los Alamitos, CA, pp. 36-41.

Kirn, St.; Heine, C.; Herrler, R.; Krempels, K.-H. (2003). Agent.Hospital - a Framework for Clinical Applications in Agentcities. In: Applications of Software Agent Technology in the Health Care Domain (Moreno, A.; Nealon, J. Eds.), Whitestein Series in Software Agent Technologies (WSSAT), Birkhäuser Publisher Basel, pp.67-85.

Klügl, F.; Herrler, R.; Oechslein, C. (2003). From Simulated to Real Environments: How to use SeSAm for software development. In: Multiagent System Technologies (Schillo, M. et al. Eds.) - 1st German Conference MATES03, (LNAI 2831), pp. 12-24.

Klügl, F.; Oechslein, C.; Puppe, F. and Dornhaus, A. (2002). Multi-Agent Modelling in Comparison to Standard Modeling In: AIS'2002 (Artificial Intelligence, Simulation and Planning in High Autonomy Systems) (F. J. Barros and N. Giambiasi Eds.) SCS Publishing House, pp. 105-110.

Krempels, K.-H.; Nimis, J.; Braubach, L.; Pokahr, A.; Herrler, R.; Scholz, T.(2003). Entwicklung intelligenter Multi-Multiagentensysteme – Werkzeugunterstützung, Lösungen und offene Fragen. In: INFORMATIK 2003 Innovative Informatikanwendungen (Dittrich, K.; König, W.; Oberweis, A.; Rannenberg, K.; Wahlster, W. Eds.), GI-Edition Lecture Notes in Informatics, P-34. Köllen Publisher, Bonn, Band 1, pp.31-46.

Oechslein, C.; Klügl, F.; Herrler, R.; Puppe, F. (2002). UML for Behavior-Oriented Multi-Agent Simulations In: From Theory to Practice in Multi-Agent Systems LNAI; Second International Workshop of Central and Eastern Europe on Multi-Agent Systems (Dunin-Keplicz, B., Nawarecki, E. Eds.), CEEMAS 2001 Cracow, Poland, September 26-29, 2001, Revised Papers Springer Heidelberg.

Willmott, S.; Constantinescu, I.; Dale, J.; Somacher, M.; Marinheiro, R.; Mota, L.; Bothelo, L.; Bonnefoy, D.; Picault, J.; Poslad, S. ; Tan, J.; Bothelo, L. (2003). Agentcities Network Architecture Recommendation. http://www.agentcities.org/rec/00001/actf-rec-00001a.pdf, [2003-02-04].