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ABSTRACT

The removal of currently existing deficits in the area of information logistics in the health care domain can significantly contribute to the improvement of quality of the care for patients, the reduction of costs, and the improved decision making process in the areas of diagnosis and therapy. IT-applications that are based on agent technology are especially suited for providing solutions to the mentioned problems.

In this report current workings of the German National Science Foundation project ASA*inlog* are presented. The concept of active, dynamic activity areas for the analysis and modelling of parts and typical properties of the application domain health care will be introduced. Furthermore, the implementation of activity areas as open and heterogeneous multi-agent systems will be described. Since the research workings are currently in progress, this paper describes an attempt to solve the previously mentioned problems.

Keywords

Multi-Agent Systems, Electronic Patient Record, Context-Sensitive Data, Integration of Heterogeneous Data.

INTRODUCTION

The enduring health care related discussion about the enhancement of the efficiency of patient care and the reduction of costs represents the significant relevance of information logistics in the area of health care. The importance of improving efficiency is derived from the following facts: increasing differentiation and specialization of funding agencies and the rising interconnectedness of all persons involved in the treatment process. Furthermore, an integrated, patient oriented, and information based treatment demands coping with a vast amount of medical and coordinative data. Additionally, means for their effective gathering, evaluation, filtering, and concatenation are required.

Taking these challenges into account, the project ASA*inlog*, Agent System Architectures for active medical documents – Information Logistics in multi-contextual domains (Reinke, 2003a), achieves new scientific contributions. These focus the further development and application of agent technology for answering questions concerning information logistics in the area of health care. Fundamental goals are as follows:

- The health care team is to be provided with necessary information, which is needed at the proper point of time and place. For that purpose, the contexts of collection and the intended application of information are to be taken into account.
- Processes of cooperation and coordination over and with the commonly used material of cooperation, i.e. the context annotated medical information, are to be supported effectively.

ASA*inlog* is a shared project, which is hosted by the German National Science Foundation Priority Research Program 1083 "Intelligent Agents in Real World Business Applications".

A description follows of significant contents of the current project workings in the form of a general survey. We focus hereby on the concept of active, dynamic activity areas for modelling parts of the application domain (section 2) and the implementation of these domain models using open multi-agent systems (section 3).

ACTIVE, DYNAMIC ACTIVITY AREAS

Typical properties of the health care domain comprise e.g. relationships of physicians and nurses for cooperation, communication, and coordination. For the analysis, the collection, and modelling of such elements the concept of active, dynamic activity areas is developed and applied within the ASA*inlog* project. It extends the modelling approaches of rooms as static working contexts (Schwabe, 1998) by adding dynamic elements like the creation, merging, and dissolving of activity areas. An activity area consists inter alia of a network of actors, their executable activities, and the attendant necessary data and tools, e.g. medical devices. It contains explicit or implicit process knowledge about the processing of tasks, their decomposition, their forwarding, and delegation. Activity areas are dynamic in terms of adding, removing, or changing of actors, i.e. their migration. Actions like making-up and finishing interactions, changing of the process knowledge, and the integration of new data sources or devices add further dynamic aspects. Additionally, activity areas are heterogeneous with respect to their properties, e.g. the used data and their storage.

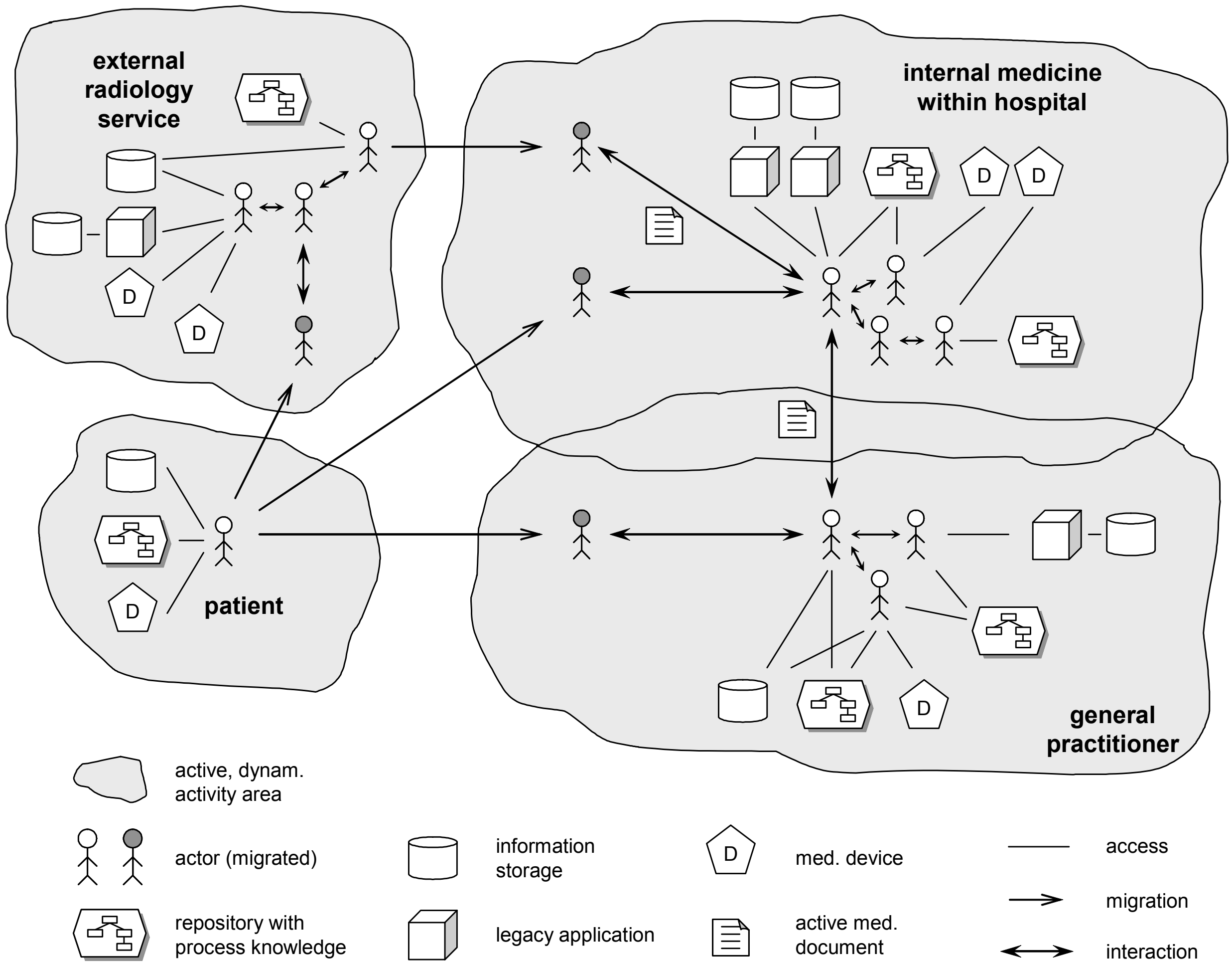

Figure 1. Active, Dynamic Activity Areas

Figure 1 illustrates activity areas exemplary for a section of the domain. Consider a patient visiting an internal medicine ward within a hospital. The patient's and the ward's activity areas including their physicians, nurses, information systems, and medical devices are merged. The information exchange between physicians regarding the medical information about the patient is facilitated by medical documents. Further information about the patient's health status is extracted from clinical information systems. Results of the physical examination, which are relevant for the aftercare, are shared with a general practitioner via medical documents.

Up to now, the diverse environments of ambulatory and in-patient treatment and external service providers like physical therapy institutions or radiology services are relatively separated from each other. This fact originates from organizational structures, the availability of data and services or legal restrictions for the protection of data privacy. The interoperability of data processing systems is prohibited by missing implementations of standards for data formats like HL7 (Health Level 7, 2004) and by missing standards for interfaces for communication and encryption techniques (Warda and Noelle, 2002). However, integrated and patient oriented treatment demands overcoming the boundaries of activity areas and their heterogeneity. By creating and connecting dynamic activity areas the isolation of the previously mentioned environments is abolished. For that purpose, e.g. decentralized controlled processes are to be connected, services are to be composed dynamically, data are to be exchanged, and legacy applications are to be integrated. When exchanging data, existing legal restrictions are to be taken into account. Here the aspects of data security and protection of data privacy are to be considered explicitly.

The health care domain deployment of data processing systems demands measurements for guaranteeing confidentiality and authenticity of medical data. Digital signatures allow for the authenticity, that identifies an author of an entry in the medical document unequivocally. The encryption of data realizes the confidentiality of data, which is particularly necessary for archiving purposes. Furthermore, the controlled and context driven access to patient data is desired. The management of access rights for accessing medical data is too complex, when performed only in dependency of the particular document (Hertweck, Krcmar and Schwabe, 1997): Access control lists for documents taking into account all possible combinations of users and access rights are very extensive. The properties of rooms with respect to the access rights of the actors to documents within these rooms are inherited by the properties of documents, which are read and written in the respective rooms. This fact simplifies the management of access rights. Thus, the context sensitive management of rights for accessing documents in rooms in dependency of these rooms is required. This new approach takes into account the fact that e.g. a physician is granted access to all medical information regarding the current treatment of his or her associated patients during a ward round. But the same physician is granted access only to partial medical information while assisting a colleague from a different ward. For adequate access control, mechanisms are to be implemented, that control the access to patient data in dependency of the context, i.e. room and information demand, and the role of the accessing person.

MAPPING OF ACTIVITY AREAS TO MULTI AGENT SYSTEMS

The present results of the project ASA*inlog* show, that agent technology (Wooldridge, 2002) is suitable for the software-based realization of active, dynamic activity areas and contributes to the solution of problems of information logistics in the health care domain. In particular, the following properties can be adequately mapped to multi-agent systems (Reinke, 2003b): inherent distribution, heterogeneity, and multiple contexts of medical and coordinative information, decentralization and autonomous behaviour of actors in the health care domain and their manifold, complex and application domain specific relationships for communication, cooperation and coordination. Software agents can be deployed for the collection and evaluation of distributed information. They allow for a high degree of personal assistance for the user, because of their proactive and reactive behaviour. Agents can be moved to those places where relevant data is available. Therefore, vast amount of data needs not be transferred to those places, where they are needed. Agents extract relevant subsets of data and transmit only these partial data. Thus, the mobility of agents forms the basis for avoiding data intensive transactions via networks and therefore saves bandwidth and processing time.

Central elements of the proposed solution are active medical documents (Reinke, Hoffmann, Horn and Krcmar, 2003). They are realized as composite software agents and as improvements in electronic patient records. These active documents encapsulate medical and administrative patient data and additional elementary agents. These agents perform tasks of interpretation and concatenation of data, arranging access control, controlling complex medical processes, monitoring appointments, associating similar disease patterns, and recommending potential therapies. Agent connectors support complex, flexible, and domain specific relationships for communication, cooperation, and coordination. These connectors are special architecture components in multi-agent systems, which allow for the encapsulation of interaction protocols. These enable semantically rich interactions between agents or between agents and the environment of the multi-agent system. For the integration of data from medical information systems and other external resources like medical devices, special adapter and wrapper agents are deployed. These agents extract relevant data from databases or information systems and translate these into a universal XML data format. These data can be transmitted and serve as input for other display devices or information systems, even for external ones. The basis is formed by XML-based HL7 clinical documents (Health Level 7, 2004).

Software agents act on behalf of their real world representatives. E.g. a general practitioner's agent negotiates with a medical document's agent, in order to be granted access to the relevant information, which is needed for the aftercare. The negotiation takes into account legal restrictions for privacy protection and the need of the general practitioner for adequate medical information.

Summarizing and systemizing the project results: multi-agent systems architectures provide a domain specific pattern-like architecture specializing a general pattern-like architecture for multi-agent systems (Horn and Reinke, 2000). Prototypes, which are based upon agent platforms, are implemented for a subset of components and subsystems of the pattern-like architecture. These allow for the technological support of realistic scenarios of the health care domain.

The mapping of activity areas to multi-agent systems for the medical domain preserves the property of heterogeneity. The latter arises from the autonomy, decentralization, and independence of actors of the health care domain. The heterogeneity becomes technically manifest in e.g. diverse agent models and platforms, mechanisms for interactions, ontologies, security requirements, or legacy applications to be integrated. Overcoming the heterogeneity in the context of the integrated patient treatment demands satisfying requirements of openness in multi-agent systems (e.g. by publication of offered services and service properties, supported interaction mechanisms, addresses, and ontologies) and the technological realization of the technical connection of diverse systems. For the latter, the already introduced connectors can be deployed, which take into account the specifics of used basic mechanisms and provide means for adaptations or transformations between environments. They can be compared to composite connectors for other types of software architectures (e.g. Object Request Broker or Messaging Systems (Horn and Reinke, 2002)), but additionally allow for semantic interactions.

CONCLUSION

The described concept of active, dynamic activity areas is an approach for modelling the health care domain with its complex processes, interactions, and medical information. The proposed solution provides means for taking into account context-sensitive medical information and processes of cooperation and coordination. But realizing these features requires further research work, which focuses on providing context-sensitive medical information. Furthermore, up to now only fixed processes are modelled. Thus, future work concentrates on means for expressing flexible processes.

Current workings of the project ASA*inlog* deal with the elaboration, application, and evaluation of the concept of active, dynamic activity areas and their implementation as domain specific multi-agent systems. Furthermore, a continuous and integrated development method for multi-agent systems is provided. This method connects the socio-scientific (ethnographic) approach of the Needs Driven Approach (Krcmar and Schwabe, 1996; Schwabe, Streitz and Unland, 2001) for analyzing domains with a software engineering, architecture-based method for the design and the construction of multi-agent systems (Reinke, 2000, 2003b). The method is described through meta-models, work-steps for the developer, and transformation models for systematically overcoming syntactical and semantic gaps (Reinke, Hoffmann, Horn and Krcmar, 2002) within the development process. Based on this method, tools for the support of the domain modeller and the software developer will be provided.

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