Agent-enabled model integration in a knowledge-based planning environment

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ABSTRACT: The field of fire protection engineering is characterized by the cooperation of experts and by the distribution of knowledge resources. The availability of relevant knowledge in all states of the planning process is the basis for a high product quality and for optimal conditions for the rescue of persons. Hence, this project aims to create a knowledge based planning environment that offers multiple services for decision support in fire protection engineering. Therefore, structured information resources (such as model and product databases) and unstructured information (such as legal guidelines and other document-based information) have to be identified and integrated. This paper focuses on the integration of distributed partial building models in a network-based planning environment. The implementation of this integration as an agent-based component and its role in the knowledge-based planning environment are presented. Different distributed design models are integrated on the basis of mobile agents. The concept of an agent-based integration of information resources is demonstrated via the implementation of a knowledge based service that checks the distributed models for compliance with fire protection requirements.

1 INTRODUCTION

This contribution is based on the research activities within the program "Network-based Cooperative Planning Processes in Structural Engineering" (DFG 2000) supported by the German National Research Foundation. This research program supports various projects within the context of the network-based cooperation and bundles different activities in informatics in civil engineering in Germany.

This work provides an approach to support the distributed and knowledge intensive planning processes of fire protection engineering. Fire protection engineering is a task that involves planners from many fields. Furthermore, not all planners dealing with fire protection problems have profound knowledge in this area. Therefore, knowledge has to be offered to the distributed planners. In this contribution knowledge is provided as services in a knowledge based planning environment using software agents.

2 FIRE PROTECTION PLANNING

Huge fire disasters have caused fire protection to become one of the central aspects for administrative authorities in the process of licensing the building design. In Germany, fire protection is divided into two domains: the preventive and the defensive fire protection. The preventive fire protection contains all structural, technical and organizational fire protection aspects. The fire fighting and rescue are aspects of the defensive fire protection. Within the preliminary planning, the elementary requirements for effective rescue and optimal fire-fighting are created by the preventive fire protection (Schneider 2000). For that purpose, the building geometry and the adjustment of escape routes are important. Furthermore, the building components' requirements are determined with regard to fire resistance. All measures to guarantee the fire protection in a building contribute to the planning objectives, which improve the safety level of a building (Klingsohr 2002). The realization of the defined protection objectives and the specification of fire protection elements in the detailed planning are an integral component of a holistic fire protection concept (Loebbert 2000). According to the type and size of a project, planners from different fields (e.g. statics, construction, heating, ventilation, electric, and geotechnics) are involved. Methods to validate the planning results with regard to completeness and effectiveness regarding the fire protection objectives must be provided. Therefore, a large number of codes and regulations concerning fire protection of buildings have to be evaluated.

The presented approach focuses on the preventive fire protection engineering. This part has to be recognized during the whole planning and construction phase and is the basis for the defensive fire protection.

3 KNOWLEDGE BASED PLANNING ENVIRONMENT FOR FIRE PROTECTION ENGINEERING

As described above, fire protection engineering is a task that includes planners from many fields. The fire protection engineer defines objectives and measures in a fire protection concept. All other planners have to consider the input of the fire protection engineer in their detailed planning. That means checking their work for fire protection deficiencies. The aim of this work is to provide a knowledge based planning environment to integrate all parties of the planning process and to provide knowledge based services to support the planners in their detailed planning regarding fire protection.

Different categories of knowledge have to be considered in this process. These are domain knowledge, corporate knowledge and project knowledge (Zarli 2001). These kinds of knowledge have to be incorporated into the building model in the course of the planning process. In this project, it is assumed that distributed planners are working on partial building models.

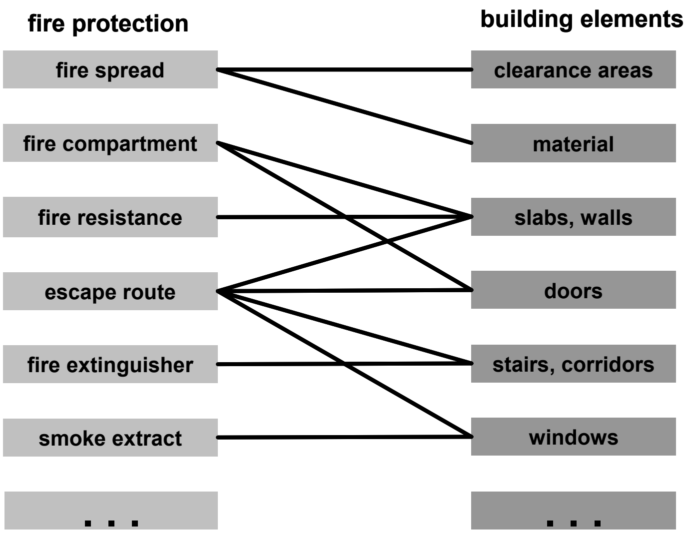

Figure 1. Interrelated partial models

The fire protection partial model is highly interrelated with other partial models. As shown in figure 1 this is due to most fire protection elements being associated with building elements. A floor in the building model, for example, can be identified explicitly as an escape route. The definition of an escape route defines special requirements on the linked building components. These requirements must be permanently checked up during the planning process. (Rüppel 2002a).

One of the planning process' main goals is to build up these partial models while preserving consistency with each other. The integration of the distributed partial models is a main precondition for the incorporation of the different knowledge sources. On the basis of the integrated partial models knowledge based services to support the planner can be implemented. The architecture of the planning environment offering different knowledge based services on the basis of the agent based model integration is shown in figure 2.

One of the knowledge based services based on the coupled partial models is the fire protection agent. This agent checks the current planning state represented by the coupled models for compliance with the fire protection requirements. To do this, the fire protection agent has to process parts of the models with the requirements from the design codes. This agent is described in section 7 of this paper.

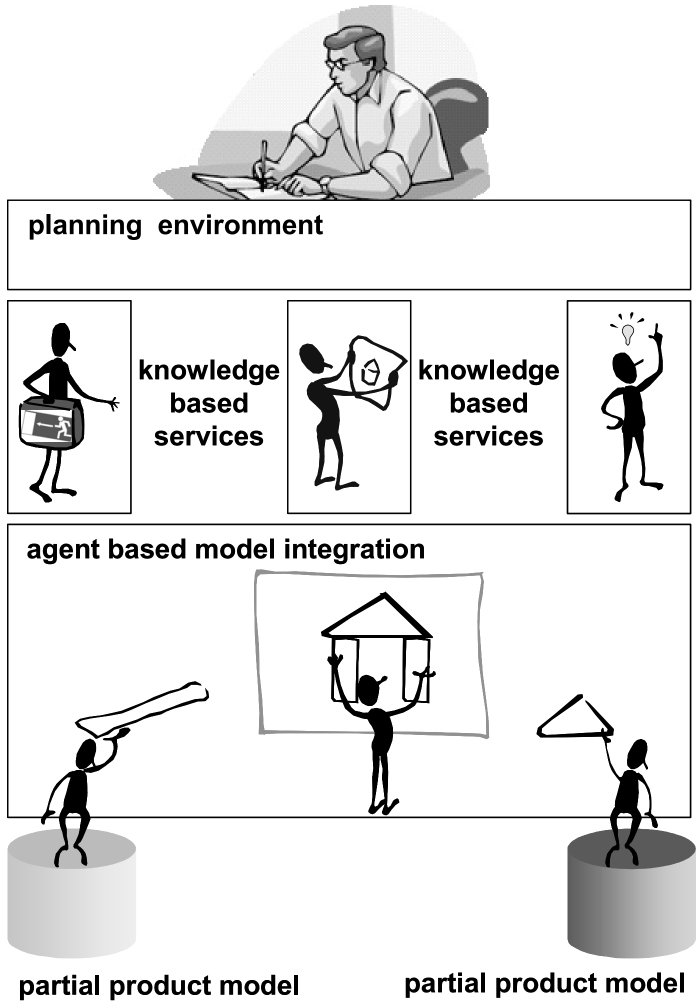

Figure 2. Agent-enabled model integration in a knowledge-based planning environment

Another knowledge based service supports the planner in the usage of project experience. It helps the planners in the process of finding solutions for new planning tasks by searching an organizational memory for similar problems. There, completed and already approved building models are stored. An approach for searching for similarity in planning tasks is described in (Lange 2004).

Further knowledge based services can be developed on the basis of the architecture described in this paper.

To evaluate this approach, a prototypical web based user interface has been implemented. This interface allows the planner to access the distributed partial models and different knowledge based services. The web interfaces provides the planner with different views of the fire protection elements of a building. Furthermore, the described knowledge based services, for example the fire protection agent, are accessible through a task bar in this user interface.

This paper focuses the integration of the partial models on the basis of a multi-agent system. The presented multi-agent system is based on the agent development framework JADE (JADE 2005) and is able to fulfill the high demands of a distributed planning process in building design on a software system concerning distribution, communication, robustness and flexibility.

4 AGENT BASED MODEL INTEGRATION

As mentioned above, the integration of partial models stored in databases is an essential task. In the developed agent system every partial model has a proxy in the form of a stationary wrapper agent on its platform. This agent answers questions regarding the underlying model representing the planning details. The transportation of the model information is supported by mobile agents (figure 3). This architecture supports a flexible integration of the partial models.

The database wrapper agents are used to integrate the relevant design information into the multi-agent system. They provide the relevant product model data to other agents in the multi-agent system, independent on their physical location. Thus, database wrapper agents act as an interface between the multi-agent system and heterogeneous database systems (Bilek 2003). The communication between the database wrapper agents and other requesting agents implies a common vocabulary, a specific database ontology mapping database related message contents to database objects. Hereby, the software-wrapping technology enables the various design experts to plug existing database systems and data resources into a specific multi-agent system. As a consequence, dynamic changes in the design information of large collaborative engineering projects are adequately supported (Hartmann 2004).

On this basis it is possible to support the planners with knowledge based services. One of these services is the fire protection agent. This agent can be addressed by every planner to check his planning for consistency with the fire protection guidelines.

The integration of the partial models on the basis of wrapper agents, information agents and ontologies is described in detail in the following sections.

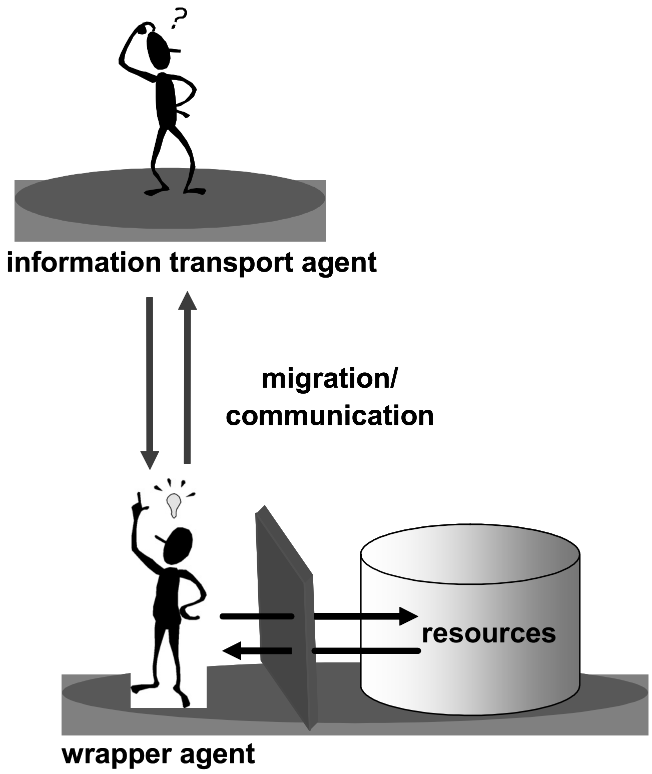

Figure 3. Agent-based model integration

5 THE WRAPPER AGENT

The Foundation for Intelligent Physical Agents (FIPA) has incorporated the concept of wrapper agents in its specifications for the design of multi-agent systems (FIPA 2005). The FIPA software integration specification makes use of so-called wrapper agents that "agentify" external resources. These wrapper agents provide a public interface to specific external resources although these resources usually cannot be accessed from other software agents in the multi-agent system directly. Wrapper agents are usually implemented in terms of stationary agents. They act on the host where the applied resource is located. Wrapper agents provide an easy to use interface to the services provided by the integrated resources. Thus, they hide the internal database structure required for accessing the encapsulated data resources. The architecture of the database wrapper agent is introduced in (Theiß 2003). The main focus in the development of the wrapper agent lies on the communication component. Two important problems have to be considered when modelling the communication between agents. Firstly, the structure of the communication process and secondly, the syntax and semantic of the message content.

To support agent communication, the FIPA has defined so-called agent interaction protocols (IP) and communication acts (CA) (FIPA 2005). An interaction protocol describes a complete communication dialogue between two interacting agents. Figure 4 shows the information-request-interaction-protocol described in AUML (AUML) (Odell 2000) that is implemented in the agent system.

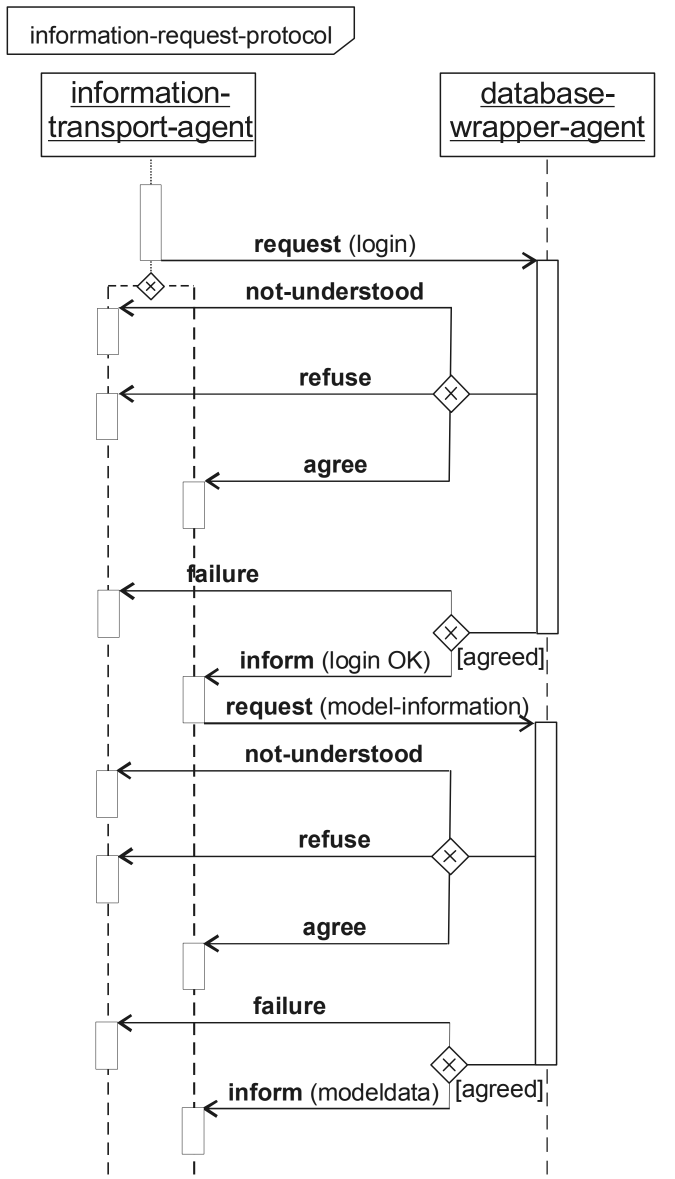

Figure 4. Information-request-interaction-protocol

The shown interaction-protocol models the interaction between the information and the wrapper agent. After receiving the CA *"request"*, the wrapper agent informs the information agent whether it *"refuses"* or *"agrees"* by accepting the received query. After a successful login, a query is passed to the wrapper agent. In case of understanding the query the wrapper agent processes the query and responds using the CA *"inform"*.

The wrapper agents as well as the querying agents need to implement the CA introduced above in terms of JADE-behaviours (JADE 2005) on a technical level.

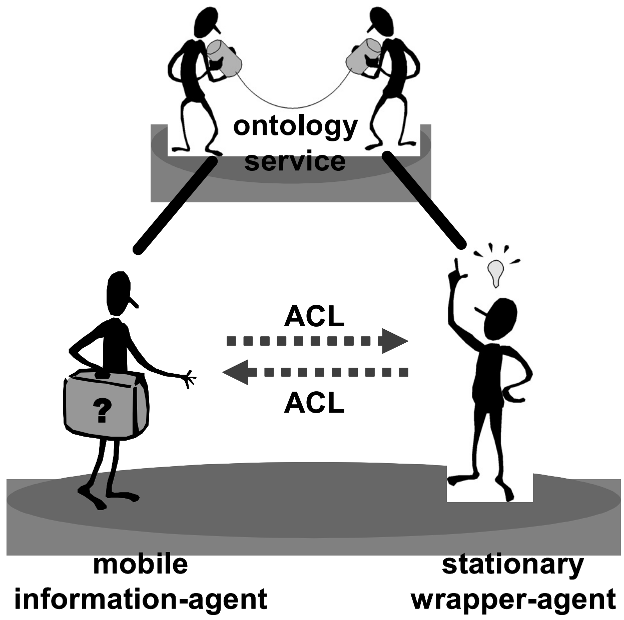

Figure 5. Agent-based ontology service

In addition to the communication acts and realized interaction protocols, ontologies have been developed which define the homogeneous vocabulary used in the message contents. A request ontology determines the query model defining the three action tags *"select"*, *"insert"* and *"update"*. The request ontology is fundamental for each database wrapper agent implementation because it matches the agent's core functionality. Depending on the project related tasks and knowledge, further ontologies are necessary to describe the specific technical contents and product models. In this project, an ontology defining the structure of a building is being implemented (Hartmann 2004). The ontology is provided to the agents by an ontology service that acts as a translator in the agent based planning environment (figure 5).

6 INFORMATION TRANSPORT IN AN AGENT BASED PLANNING ENVIRONMENT

As shown above the different partial product models have to be retrieved by an agent for processing purposes. The information transport agent outlined in this section offers the service of information transport in the network based planning environment. The information transport is divided into two steps. The first step is the transport of the query to the database wrapper agent; the second step is the transport of the response from the database to the initiator of the query. Thus, the information transport agent features two main characteristics: mobility and communication.

The multi-agent system consists of several agent-platforms. One platform can comprise several computers, whereas an agent can migrate within this platform. For the inter-platform migration of agents a new service has to be developed. Every platform with inter-platform agent migration support has to instantiate this service. The service offers sending and receiving of agents. The process of agent migration contains several steps: after starting the migration process, the agent class and all inner classes are packed. To restart the agent, all starting parameters have to be saved and packed as well. Before sending, all data collected on the platform has to be packed. Then the result is transformed into the content of an Agent-Communication-Language(ACL) message. The content is hashed by a MD5 hash key for security reasons. Finally, the message is sent to the agent migration service of the destination platform. The process of reactivating the agent after migration corresponds to the sending process in reverse order. Thus, a multi-agent system with inter-platform-mobility could be realized.

For communication the information transport agent uses the same ontology and interaction protocols as the database wrapper agent described in this article. In (Hartmann 2004) the communication is shown in detail. By the use of the described communication interface, and the shown migration service, an information transport agent is enabled to query and to receive model data. The transport agent analyzes the address of the building planner and migrates to his platform. On this platform, the agent starts to communicate with the local database wrapper agent and hands out the query for the model data. This query will be mapped to the local database schema by the database wrapper agent. The database response will be mapped to a public building model ontology and passed on to the waiting information transport agent. This agent migrates back to the initiator with the result. An application for this agent based model integration is given in the next section.

7 A KNOWLEDGE BASED SERVICE: THE FIRE PROTECTION AGENT

On the basis of the described agent based model integration, knowledge based services are implemented and provided to the planner in a planning environment. In this section the "fire protection agent" is presented as one of these services.

In Germany, fire protection as well as building design supervision is the sovereign right of the federal states. Their codes differ in details in every state. In result, there is a great number of design codes and special building regulations (for multistorey buildings, hospitals, etc.) (Rüppel 2002b). To comply with these complex standards completely and without errors during the design process is a challenge in collaborative fire protection engineering (Meißner 2004).

To enable the validation of fire protection requirements, the fire protection agent has been integrated into the knowledge based planning system. The agent has to be able to process the facts of the building's fire protection model in accordance with the requirements from the design codes. The rules in fire protection are declaratively styled. Rule-based expert systems are well known in processing declarative rules. The Java Expert System Shell (Friedmann-Hill 2003) is one of the most used rule-based expert systems and is the reference implementation for the Java Rules Engine API. JESS is Java-based. The Jess API can be integrated directly in an agent of the Jade system. Rule-based systems work with rules and facts. An example for a fact is the width of an escape route; the corresponding rule is that every escape route must have a minimum width of 1.25 meters.

The fire protection agent has to process information from all involved models (Meißner 2003). At first, the relevant fire protection element has to be identified in the fire protection model. Thereafter, all relevant fire protection rules have to be retrieved from the fire protection rule model by the information transport agent and the corresponding database wrapper agent. In addition, the corresponding planning model elements have to be retrieved from the building model databases in the same way. After retrieving all information, the fire protection agent checks whether it has all facts to process the rules. This is an iterative process. So, step by step, all rules and facts needed for the fire protection requirement check are transported to the fire protection agent. As a result, the fire protection elements can be checked for accordance with the valid fire protection regulations. This approach enables the planner to check his design for consistency with the fire protection objectives.

8 CONCLUSION

This paper presents the idea of a knowledge based planning environment to support planners in fire protection engineering tasks. The integration of the partial models of the different planners has been identified as a basic precondition for providing knowledge based services. This integration has been implemented by use of a multi-agent system which fulfills the requirements of the distributed planning process concerning distribution, communication, robustness and flexibility. Thereby, the integration of information resources by means of wrapper agents and the information transport in the distributed planning environment by means of information agents have been implemented. As an example for a knowledge based service working on the integrated models the fire protection agent has been introduced. This agent supports the planners by checking the current planning state, represented by the coupled models, for compliance with the fire protection requirements.

The presented agent-enabled model integration is the basis for the development of further knowledge based services working on the coupled models and consequently for the extension of the described knowledge-based planning environment.

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