NETWORK-BASED CO-OPERATION PROCESSES
FOR FIRE PROTECTION PLANNING

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SUMMARY

To avoid personal and property damages a building has to be planned in accordance with the valid fire protection guidelines. Also with respect to structural alterations the fire protection is a dominant aspect. In order to guarantee the protection objectives in all planning phases, the planning information has to be provided to all designers. Each designer supplies planning information which must be incorporated and considered by other designers. In every building project a new composition of planning partners, processing the distributed information, has to be established. The research project, presented in this contribution, supports the fire protection oriented collaboration between planning partners through the creation of a co-operation network on the basis of software agents. A network-based co-operation platform to support the process-oriented planning activities has been developed. With regard to the dynamical communication between planning participants a system design with Petri-Nets is presented for process modeling. In addition, the verification of planning steps is enabled by decentralized communication methods in the network. In accordance with their characteristics software agents are well qualified to support the co-operative planning in this network-based environment.

INTRODUCTION

The contribution presented is based on the research activities within the programme “Network-based co-operative Planning Processes in Structural Engineering” [DFG 2000] supported by the *Deutsche Forschungsgemeinschaft (DFG)*, the German National Science Foundation. This research programme supports various projects within the context of the network-based co-operation and bundles different activities in Informatics in Civil Engineering in Germany (http://www.dfg-spp1103.de). In order to find solutions for problems arising from distributed planning four working groups are established, addressing on network-based process modelling, network-enabled product modeling, software agent technologies and distributed simulation.
The aim of this research is to develop a network-based co-operation platform for the support of process-oriented planning activities in Structural Engineering. As an example the special regards of fire protection engineering were chosen to model the dynamics of planning processes within a computer network.

FIRE PROTECTION PLANNING FOR BUILDINGS WITH SPECIAL PURPOSE

Fire protection planning in building design is a dominant aspect for the prevention of fire and for the protection of life and property in the case of fire. Fire protection may be divided into two domains, the preventive and the defensive fire protection. The preventive fire protection contains all structural, technological and organizational fire protection aspects. The fire fighting and rescue are aspects of the defensive fire protection (figure 1). Within the preliminary planning the elementary requirements for an effective personal safety and an 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, requirements for the building components are determined with regard to the fire resistance.

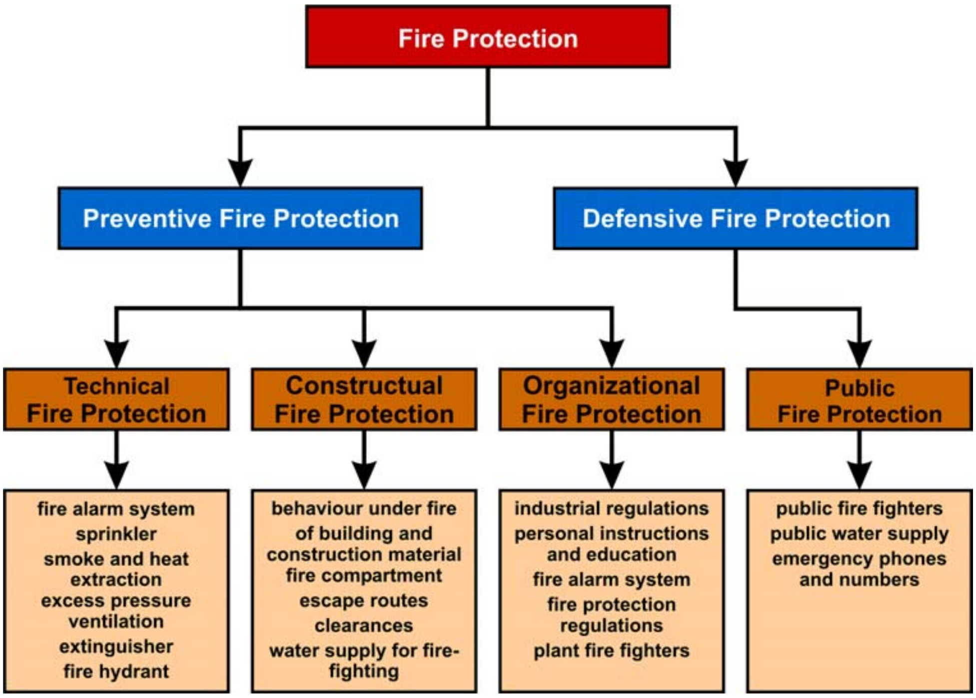

Figure 1 Structuring of Fire Protection Planning

All measures to guarantee the fire protection in a building co-operate for planning objectives, which improve the safety level of a building [Klingsohr 2002]. Next to the definition of the protection objectives and the specification of elements for fire protection, its realization in the detailed planning is 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, electrics, geotechnics) are involved. In order to avoid inconsistent planning states and failures in the flow of information between these planners it is necessary to establish a network for communication. This network must include the activities of planners as well as the state of models and the flow of information. Furthermore, methods to validate the planning results with regard to completeness and effectiveness must be provided.

A NETWORK-BASED CO-OPERATION PLATFORM FOR STRUCTURAL ENGINEERING

Typically, the project realisation in Structural Engineering is based on a multi-variant co-operation between numerous engineers and planners. In order to fulfil a specific design task planning participants dynamically form a communication network. Within such a communication network each planning participant performs special planning activities, requiring certain input information and producing certain output information necessary for other planners to fulfil their planning tasks. In order to adequately support this co-operation, moreover in heterogeneous computer networks, appropriate software methods have to be developed.

An Integrative Process Model

These software methods have to rely on a comprehensive process model. In Meissner [Meissner, 2002] the idea of an integrative process model, which includes four layers, is developed:

- The *resource layer* storing objects and their model states during planning. Furthermore this layer includes the rules and methods needed to process the model information.

- The *actor layer* modelling planners and organisations involved in the process and having control over models and decision making.
- The *communication layer* modelling the dynamic interaction flow of information between the planning participants. This layer is most important for direct access to information, eventually based on modern communication technologies like mobile software-agents [Rueppel/Meissner/Theiss 2002].
- The *co-ordination layer* representing the flow of work within planning. Petri-Nets [Petri 1962] supply a suitable theory to model this process [Katzenbach/Meissner/Rueppel, 2002].

Figure 2 illustrates the idea of an integrative process model for Structural Engineering and its four layers.

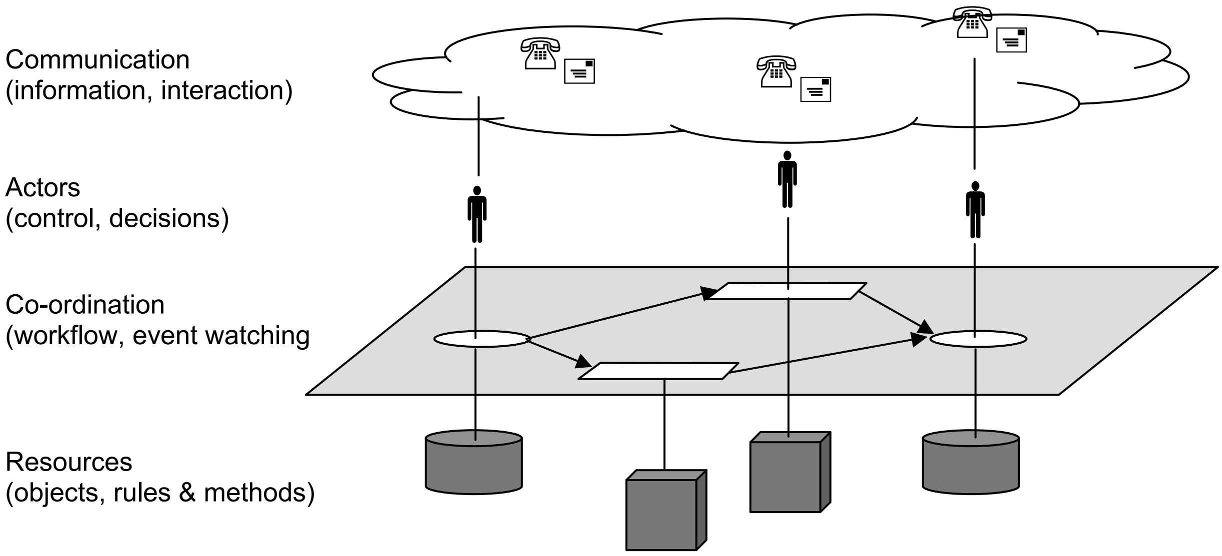

Figure 2 Integrative Process Model

Process Modelling with Petri-Nets

Petri-Nets supply a theory for the modelling and control of concurrent and asynchronous planning processes in a distributed environment. They provide a mathematical formalism for the definition and representation of a discrete system, e.g. [Kusiak/Yang, 1993]. By means of tokens the dynamic behaviour of a system is enabled. In particular, Petri-Nets with individual tokens (Coloured or Higher Petri-Nets) allow the use of semantic information for decision modelling. The Petri-Net theory is well known in computer science and was originally developed by Carl Adam Petri [Petri, 1962]. Throughout the years, further contributions have extended the original method, e.g [Jensen, 1996]. In the late 90th van der Aalst [Aalst, 1998] and Oberweis [Oberweis, 1996] introduced the application of Petri-Nets to process modelling.
Basically, Petri-Nets consist of places *p* and transitions *t*. Places and transitions are connected by directed arcs. Places can hold tokens. In Coloured Petri-Nets additional information can be attached to each token. The basic idea in modelling planning processes with Petri-Nets is to model planning states with places, planning activities with transitions, relations between planning states and planning with arcs and information with (coloured) tokens. Figure 3 shows the elements of a Petri-Net and a sample net.

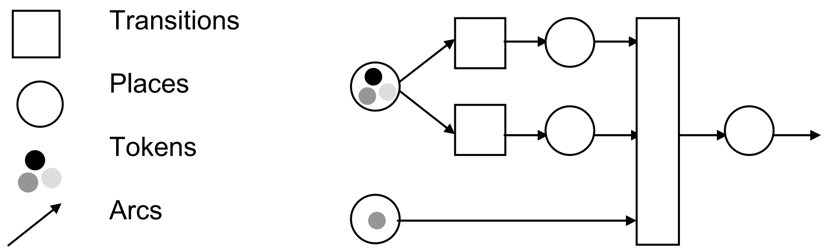

Figure 3 Process Modelling with Petri-Nets

CAD-BASED FIRE PROTECTION MODELING

The interpretation of a fire protection concept is the task of an experienced planner in result of the text-based description. For the processing of a fire protection concept in a distributed network of planners a transparent model is necessary. Thus, a new fire protection model was developed and implemented in the CAD-system Autodesk Architectural Desktop (figure 4).

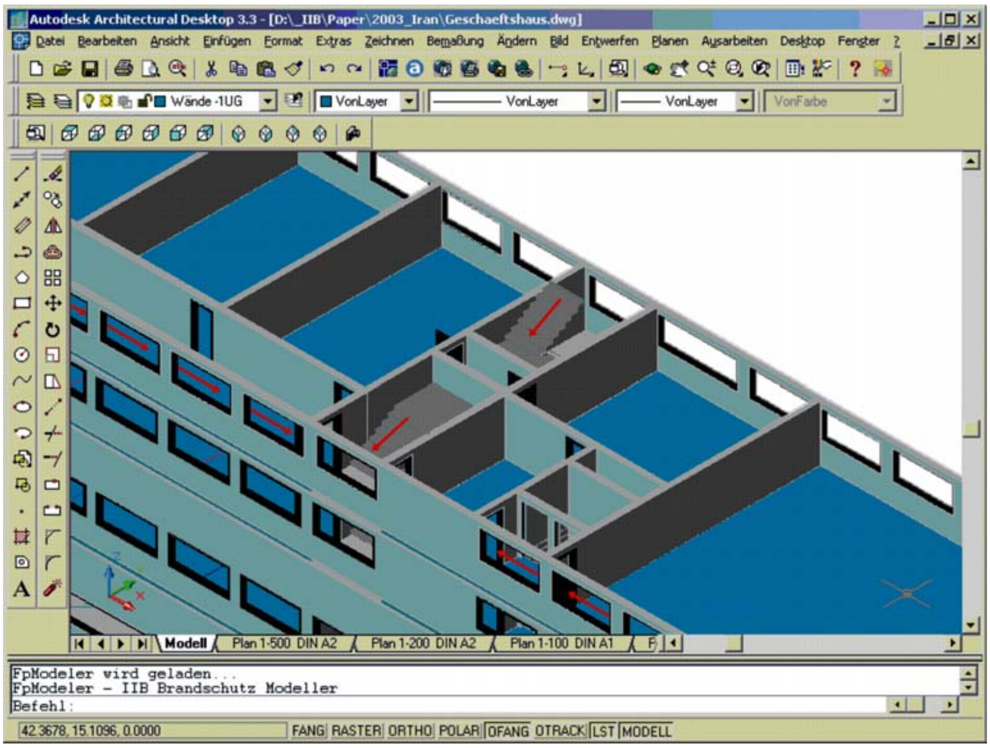

Figure 4 Fire Protection Modeling with CAD

Within this approach the definition of requirements and elements of the preventive fire protection in a three-dimensional model [Theiss 2001] is possible. During creation of the fire protection model the new information is directly associated with the building model. 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. The floor and the walls are already linked together in the building model, so that this connection can be used to check up these requirements [Rueppel, Meissner, Theiss 2002].

After instantiating the elements of the fire protection model the planning information have to be made available to all planners. Especially, the civil engineering planning process is characterized by the use of many applications with proprietary data formats. For an effective collaboration the data exchange has to be defined in a neutral data format. According by the fire protection model is parsed to XML, based on the specifications of the IAI [ifcXML, 2000]. To store the model the XML-database Tamino [Software AG 2002] is used. This database is accessable through the internet by the use of wrapper-agents (figure 5). In result all planning information is available to all planners in a neutral format and current planning states can be determined every time. The use of wrapper-agents establishes a high level of autonomy for processing and delivering of planning information.

The characteristics of software-agents to communicate with each other offer the possibility of a co-operative publishing of the planning information. Data protection is guaranteed through the unique identification of the querying agent. If it is not possible for the wrapper-agent to answer a query he can contact his planner to deliver the information. This new query type will be available by the wrapper-agent for future actions.

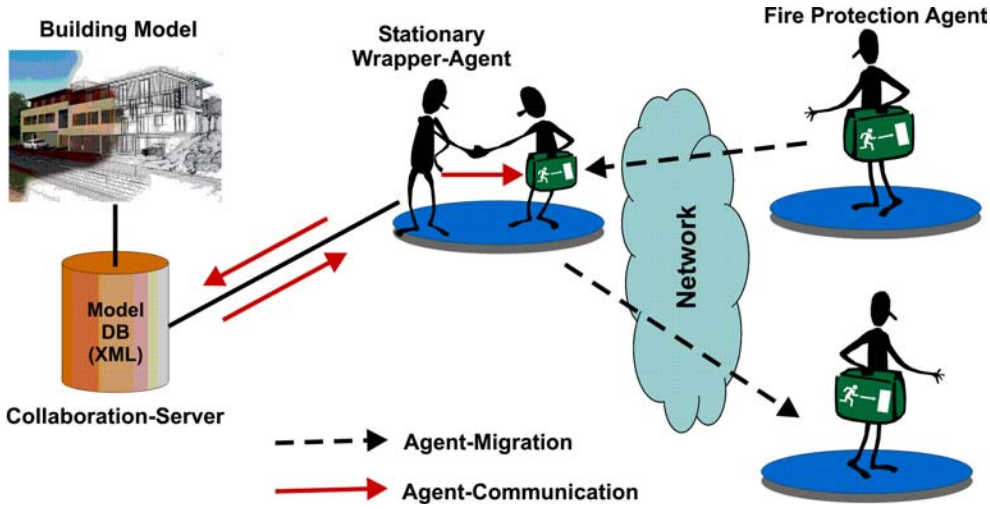

Figure 5 Supply of Information by a XML-Based Database and Wrapper-Agents

RULE-BASED PROCESSING OF PLANNING INFORMATION

The definition of a pure data model is not sufficient to check up the planning information for fire protection. The information defined in a fire protection concept is associated with the rules from regulations and guidelines which must also be modeled. A processing of this knowledge can be realized by the efficient combination of model data and rules. Therefore, a three-tier knowledge model for the preventive fire protection was developed (figure 6). On the one hand this model consists of the already described data models for the building, on the other hand of the rule model to represent the guidelines and regulations of fire protection.

For processing the rule model in the co-operative planning network with the data models, the rules must be defined and structured in a processable form. The rules are structured in a first step by the type of the regulation in a second step by the related building element. This approach enables an object-oriented processing of necessary rules. The rule structure optimizes the validation process as well as the communication process for acquiring necessary rules.

By means of a problem-specific user interface (figure 7) the CLIPS-based rules [CLIPS 2002] can be defined in a graphic editor, to be processed and to be integrated in the above described structure [Theiss 2002]. Also complex rules can be set up conveniently by the combination of several rules.

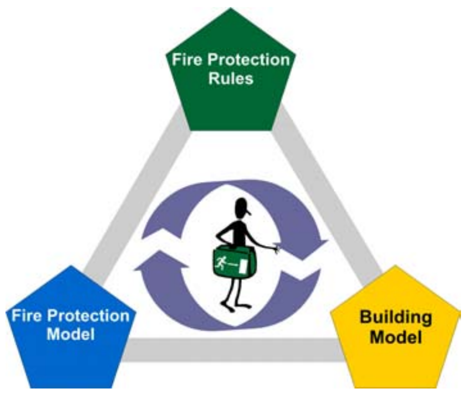

Figure 6 Three-tier Architecture to Model and Process Fire Protection Information

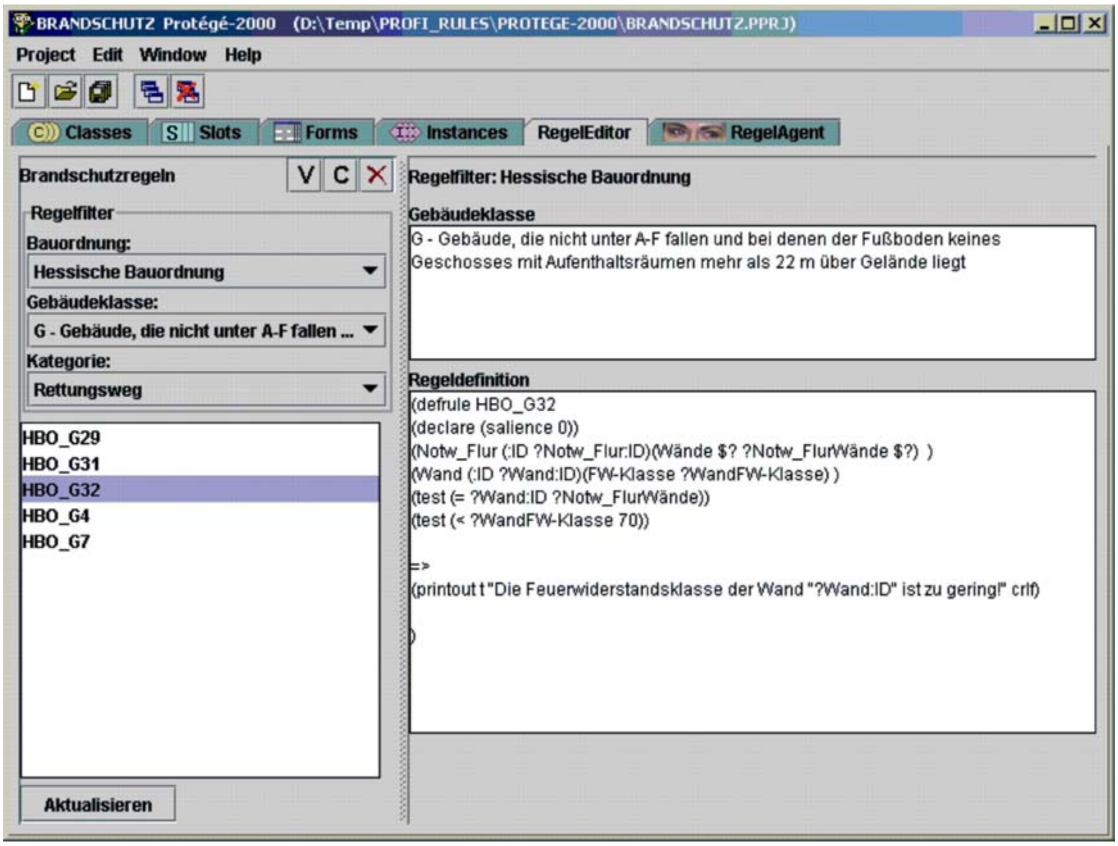

Figure 7 Editor for Defining Rules of Fire Protection Element Validation

AGENT-BASED CO-OPERATION FOR PREVENTIVE FIRE PROTECTION PLANNING

To enable the validation of fire protection requirements for all co-operating planners, the rule-based fire protection processing has to be integrated into the co-operation network as well as the building and the fire protection model [Meissner/Rueppel/Theiss 2002]. The agents are the digital proxies of the planners in the network; sharing necessary information to authorized co-operation partners or gathering information for their associated planner. Furthermore, appropriate processing methods for the verification are provided with an agent and can be used by the planners.

The agent system was developed with the Jade-System (Java Agent Development Framework) [Bellifemine 2002] consisting of different agent types, which can be instantiated by each planner. To transport and acquire planning information transport-agents were developed. A transport-agent gets a task from his principal to query fire protection rules or other planning information. They can be instantiated by planners and also by other agents. Supported by a directory-facilitator-agent (“yellow pages”) the transport-agent can search for corresponding services or information providers. After contacting its partners the agent obtains the information from wrapper-agents.

In order to process fire protection guidelines with the three-tier-model, the fire-protection-agent has to appraise information from the involved models. This can be done in three steps. At first, the relevant fire protection element has to be identified in the fire protection model. There after, all relevant information can be appraised from the building model. Finally, all relevant rules for the fire protection element are appraised from the rule model [Rueppel/Theiss 2002] [Theiss 2002]. These main steps of processing fire protection information are supported by several agents. As illustrated in figure 5 a mobile agent migrates between different planning partners. He is enabled to process the information in a rule-based expert system. In addition, he can tell other agents to collect relevant information from the planning partners. To handle the communication between the mobile fire protection agents and the stationary model agents, two types of ontology are established on the basis of the FIPA-ontology-specification [FIPA 2001]. The fire protection model ontology (FPMO) describes the structure of the fire protection model. Every agent who uses this ontology knows the fire protection model to process the model information in the right way. The second ontology is the fire protection communication

ontology (FPCO). This ontology describes typical communication between agents in association with processing fire protection information [Mueller 2002].
A tool to model the fire protection ontology is shown in figure 8. This snapshot displays the rule definition tool for fire protection guidelines. According to the FPMO the hierarchical structure of the fire protection model is shown. By this tool instances of the fire protection model can be created and for each instance fire protection rules can be comfortably defined (figure 7) and published to the stationary wrapper-agent. This agent is enabled to communicate with every fire-protection-agent who uses the FPCO. A precise processing of building models with fire protection information is possible.

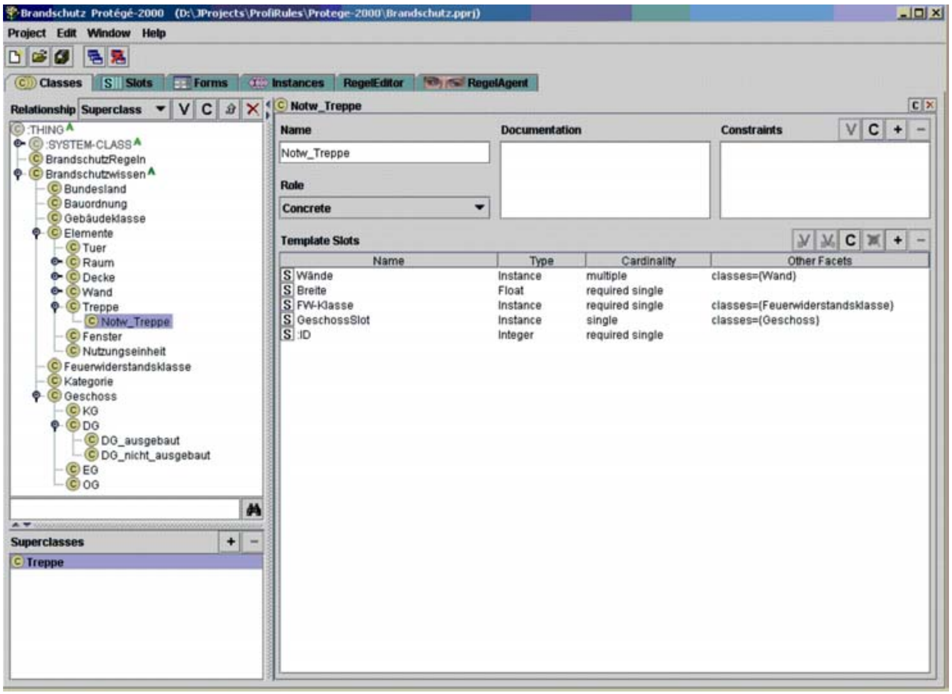

Figure 8 Editor for the Fire Protection Modeling Ontology (FPMO)

To process the fire protection rules the rule-based expert system Jess (Java Expert System Shell) [Friedmann 2001] was implemented and integrated into the fire-protection-agent.
The acquisition of information is efficiently realized by the determination of elementary information on startup of the verifying task. This elementary information is i.e. the site, the type and the use of a building. Thus, regulations can be determined and requested. During the process of verifying the necessary information are gathered step by step through transport-agents. As a result the fire protection elements have been checked in accordance with the valid fire protection regulations. This provides the planner with the possibility to check his design at every time for consistency with the required fire protection model.

CONCLUSION

The consistent definition and development of fire protection models in the building planning process is essential for the protection of life and property in the case of fire. The research project, described in this paper, makes fire protection planning information available in a network by XML-databases. Furthermore, it enables the processing of this information for all planning partners. This is activated by software agents supplying processing methods within in the co-operation network. An autonomous exchange of model information is established by the definition and use of a problem-specific communication and model ontology. The planner can check his design at every planning state by use of a fire-protection-agent in accordance with the fire protection requirements. The fire-protection-agent analyzes the design and detects inconsistencies. The possibility to check the planning information at an early state against the knowledge of the fire protection regulations enables a comprehensive diagnosis of the design and the elimination of planning errors.

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