SIREAM – AN AGENT-BASED VIRTUAL MARKETPLACE FOR AEC-BIDDING

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Abstract

Within the last years several virtual marketplaces for the building industry have been established. Time-consuming tasks like locating contractors and bidding out projects are facilitated by publishing bid documents on the marketplace, receiving responses electronically, etc. Here, the documents are no longer paper-based. It can be pointed out that these marketplaces act as document exchanges and provide little automation compared to what is conceivable.
A completely new approach is to use software agents to facilitate and to accelerate the bidding process. Software agents autonomously act and participate in the bidding process as humans did before. This paper deals with software models for an agent-based virtual marketplace for AEC-bidding (SiReAM). Besides general legal conditions in Germany the architecture of SiReAM is described in detail. Further on the ontology and the implemented standard specifications for tenders in XML which represent the basis of conversation of the agents on the marketplace are explained. Thereafter the implementation of the Public Key Infrastructure and the Java application LVAgent are presented.

1. Introduction

Today's procedures for the awarding of public construction performance contracts are mainly document-based. Beyond this building owners and construction professionals have to find qualified and competitive trade partners on their own. These are very time and cost consuming procedures which can be facilitated and accelerated using software-agents.
The development of an agent-based virtual marketplace for AEC-bidding according to legal regulations is an entirely new approach from a technical as well as from a legal point of view. The objective of this research project is the development of intelligent software-agents which are able to legally call for bids, to calculate proposals, and to award the successful bidder.

The project is sponsored by the German Science Foundation (DFG). The technical and legal requirements are analyzed and implemented in close co-operation with Prof. Dr. jur. A. Rossnagel (Kassel University).

2. SiReAM

The abbreviation for SiReAM "**Si**cherer **Re**chtsgemaesser **A**gentenbasierter **M**arktplatz" translated into English means "secure agent-based marketplace according to legal regulations". SiReAM will be described more detailed in the following chapters.

2.1 General legal conditions

In Germany public tendering procedures are regulated by the "official contracting terms for the award of construction performance contracts" (VOB, May 2000). Here the usage of electronic means for AEC-bidding is permitted.
The VOB, May 2000, was mainly influenced by the "directive of the European parliament and of the council on the coordination of procedures for the award of public supply contracts, public service contracts and public works contracts". In case that electronic means shall be applied the VOB refers to the German Digital Signature Act. The certificates which have to be used within a public key infrastructure have to be ISIS-MTT compliant. ISIS-MTT which is a subset of the X.509 v3 standard specifies the technical requirements according to the German Digital Signature Act.
Although the usage of electronic means is permitted in the VOB, the regulations are not sufficient yet. Especially software agents within the AEC-bidding process were not considered at all. Consequentially the agent-based marketplace considers the primary ideas and regulations of the VOB: Contracting authorities shall take all necessary steps to ensure compliance with the principles of equality of treatment, transparency and non-discrimination.

2.2 Architecture of SiReAM

SiReAM is an open marketplace for distributed software-agents. The legal regulations affect the architecture of the marketplace to a great extent. Especially the principle of non-discrimination demands that everybody must be able to participate in the agent-based public tendering procedures. As a consequence of this SiReAM is divided into a user section and an agent section (Fig. 1).
For the implementation of SiReAM the ZEUS Agent Building Toolkit was used. ZEUS is an open source software for building multi-agent systems [9]. It is a synthesis of established agent technologies with novel solutions to provide an integrated collaborative agent building environment [10]. ZEUS-agents act deliberatively, goal-directed, and rationally. They are always truthful when dealing with other agents and they are versatile, i.e. they can pursue many goals and can be engaged in a variety of tasks.

2.2.1 UserSection

The *UserSection* of SiReAM (Fig. 2) provides access to the currently published specifications. Potential contractors enter this section by using a common browser. The software for the generation of agents and for participating in the agent-based AEC-bidding procedure can be downloaded there as well.
The administrator of the marketplace can start, control and terminate the so-called utility agents in one part of this UserSection via a password protected secure connection. It is also possible to verify the status of these agents.

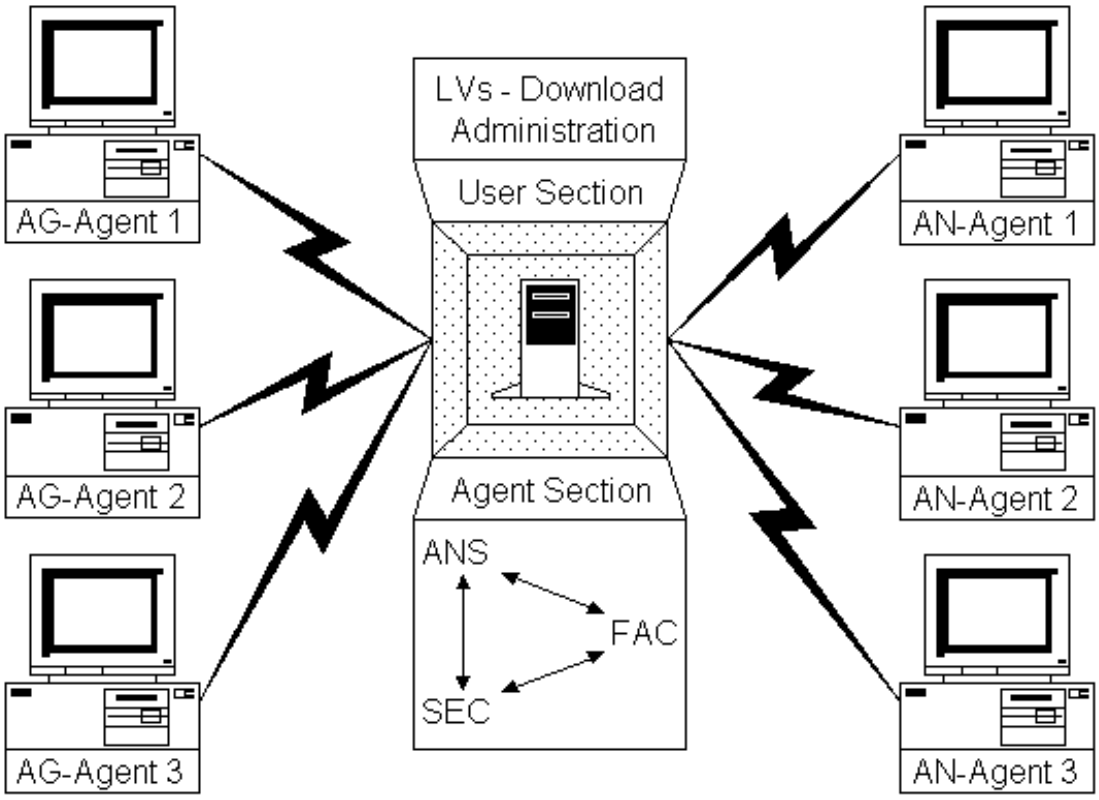

Fig. 1: Architecture of the distributed agent-based virtual marketplace SiReAM

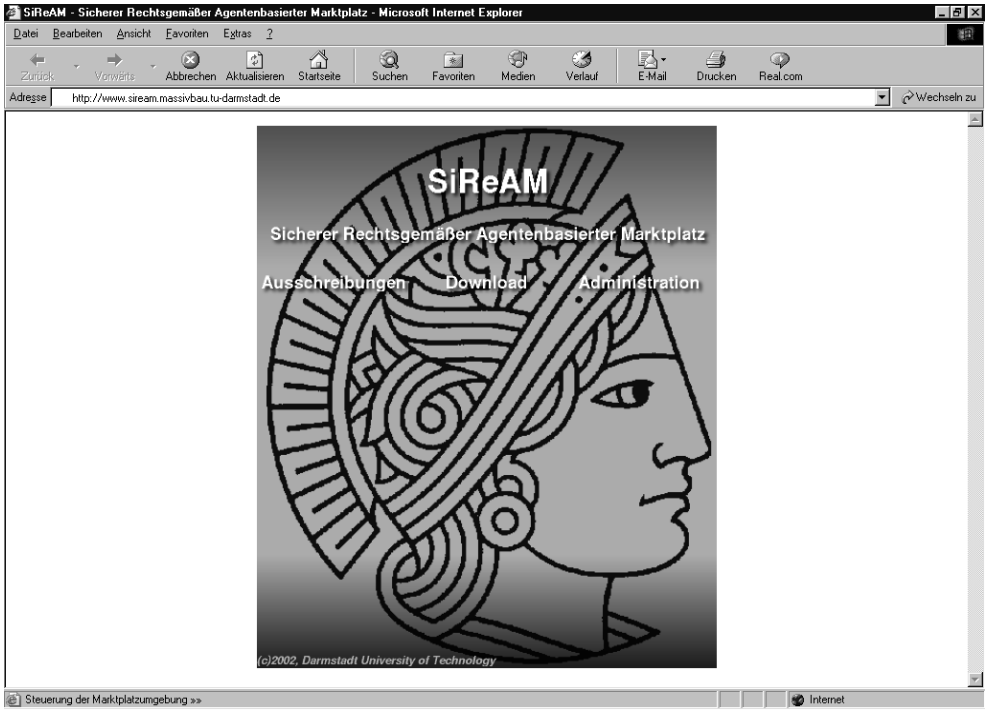

Fig. 2: User section of SiReAM

2.2.2 AgentSection: Task Agents – Utility Agents

In the *AgentSection* agents are distinguished into *UtilityAgents* and *TaskAgents* (see Fig. 3).

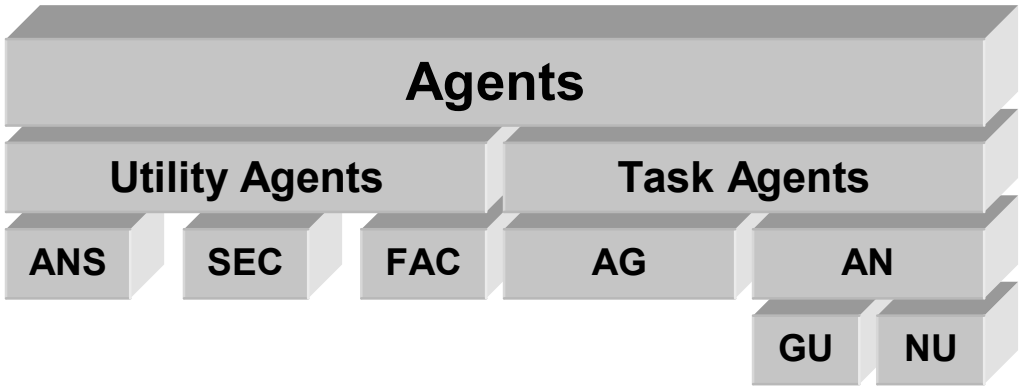

Fig. 3: Classification of the agents within SiReAM

The marketplace is operated by three different kinds of utility agents:

1. The Agent Name Server (ANS) manages the IP-addresses of the distributed software agents. Depending on the number of agents which are registered on the marketplace one or more ANS can be created for fulfilling this task.

2. The Security Agent (SEC) provides the security relevant services for a public key infrastructure which are required by the Digital Signature Act.
3. The Facilitator (FAC) asks newly registered task agents for their abilities and stores these information in a database. Task agents which have to cooperate with other agents in order to achieve their goal can obtain the names of other task agents which have the required ability. The Facilitator can be compared to the "yellow pages".

The task agents are subdivided into owner-agents (AG-Agents) and contractor-agents (AN-Agents).
AG-Agents perform the following tasks, they

- publish specifications for tenders on the marketplace,
- receive sealed bids from AN-Agents,
- decrypt the bids at the final date,
- inform their users (owners) about the received proposals,
- inform the AN-Agent which is awarded,
- and reject the proposals of AN-Agents which are not awarded.

AN-Agents can be subdivided into agents for general contractors (GU-Agents) and agents for subcontractors (NU-Agents).
After an AN-Agent has been registered on SiReAM it waits for calls for proposals (cfp) which are published by the AG-Agents. For example if a GU-Agent receives a cfp-message it starts calculating a bid based on the specifications for tenders. Services which cannot be provided by the GU-Agent itself are purchased from NU-Agents. The GU-Agent can either negotiate the price or can directly accept the proposed price of the NU-Agent. Corresponding strategies will be implemented in future.

2.2.3 Ontology – LVML

The term 'ontology' describes a "theory concerning the kinds of entities and specifically the kinds of abstract entities that are to be admitted to a language system" [11]. A software agent using a particular model of these entities will only be able to perceive that part of the world that its ontology is able to represent. Only the items in its ontology exist for that agent, i.e. an ontology becomes the basic level of a knowledge representation scheme for an agent.
On an agent-based virtual marketplace for AEC-bidding software agents have to deal with building materials and services. Thus the vocabulary of the agents must be composed by the contents of standard specifications for tenders. In order to develop a vocabulary in which the format as well as the data of the specifications are described the eXtensible Markup Language has been used to create the LVML (LV=**L**eistungs**v**erzeichniss, standard specification for tenders). The structure of the LVML is defined by a Document Type Definition (DTD). The LVML consists of six hierarchically ordered main elements:

1. LV: the name of the contracting authority, the name of the project, and final date for the submission are declared by attributes of this element.
2. Title: building shell, in-house engineering...

3. Division: sitework, concrete, masonry...
    4. Section: concrete formwork, concrete reinforcement...
        5. Position: structural cast-in-place concrete, reinforcing steel...
            6. LVText, amount, unit, unit cost, cost

The ontology defines the facts the agents have to deal with. Because the ontology used by generic ZEUS agents is not implemented in XML yet, the LVML had to be converted into the format a generic ZEUS agent can understand (Fig.4).
For the conversion it also had to be considered that the structure of the ontology is of crucial importance for the definition of the *tasks* which are specified by the *facts* and which the agents have to conduct in order to achieve their goal.

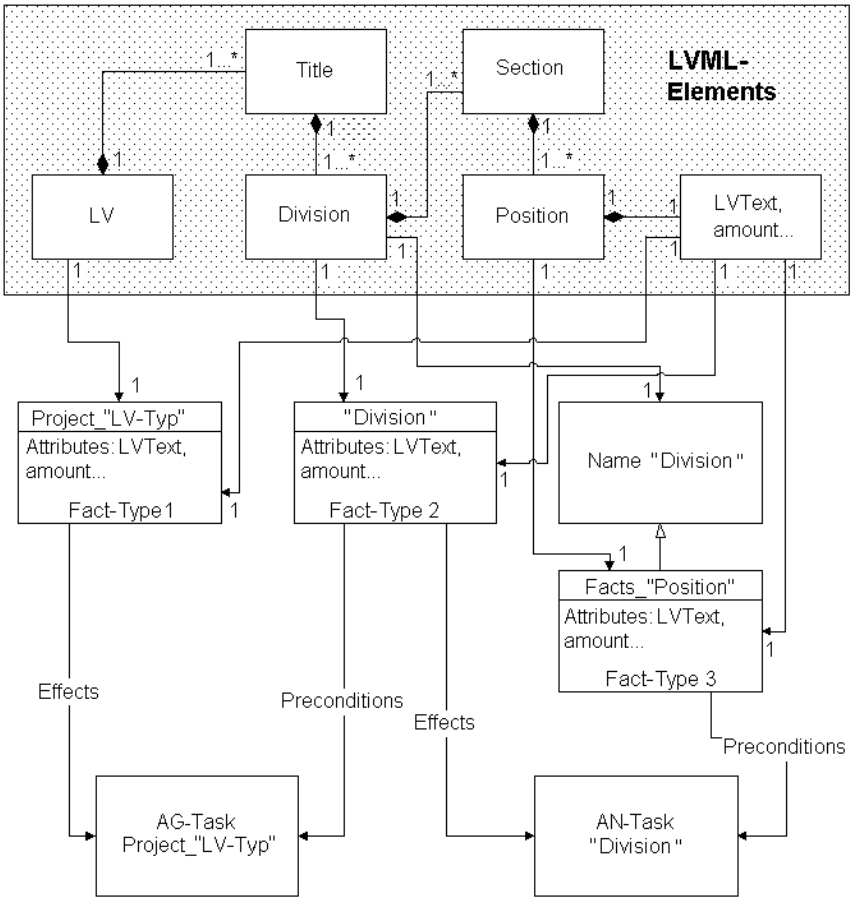

Fig. 4: Using data from the LVML-document to create facts and tasks

2.3 PKI

In general a public key infrastructure (PKI) enables users of a basically unsecured public network such as the Internet to securely and privately exchange data. This exchange is conducted through the use of an asymmetric key pair (private and public key) that is

obtained and shared through a trusted authority. The public key infrastructure provides for a digital certificate and directory services. The digital certificate is used to identify an individual or an organisation. Directory services are needed to store and, when necessary, revoke the certificates [2].
Usually a public key infrastructure consists of:

- A certificate authority (CA) that issues and verifies digital certificates. A certificate includes the public key and/or information about the public key.
- A registration authority (RA) that acts as the verifier for the certificate authority before a digital certificate is issued to a requestor.
- One or more directories where the certificates with their public keys are held.
- A certificate management system.

In a public key infrastructure a so-called chain of trust has been built. At the beginning an accredited certificate authority (CA) is located which confirms the trustworthiness of the next entity within the chain. This entity again can certify another entity and so on. In order to keep the chain of trust relatively short some entities receive end user certificates, i.e. they are not allowed to certify other entities.

Employees or associates of any company only receive end user certificates. Hence the task agents of SiReAM cannot obtain an own certificate according to the Digital Signature Act, i.e. a different way has to be chosen for authenticating the agents.
Therefore on SiReAM agents obtain a self-generated certificate which is digitally signed by the end user. The agent´s self-generated certificate is sufficient for establishing SSL connections and the agent is authenticated due to the signature of the end user. In order to distinguish the self-generated certificate from the accredited end user certificate, in the following the first one is named agent-certificate and the second one user-certificate.
The user-certificate is not only used for authenticating the agent, but also to enter contracts: Before any contract is made legal and binding by an agent the user has to grant its permit. Then the contract is signed with the private key which belongs to the user-certificate [6].

2.3.1 Scenario of a registration and working on SiReAM

Owners and contractors have to possess a certificate from an accredited CA in order to participate in SiReAM. Then the registration process can be explained by the following scenario (see Fig. 5):
After Company A has received its certificate it digitally signs its Agent A or more precisely the agent´s self-generated certificate. Now agent A sends this agent-certificate, the signature, and Company A´s user-certificate to the Security Agent. The Security Agent verifies the signature by contacting the CA. If the signature is valid the Security Agent can clearly assign Agent A to Company A and stores the agent-certificate in its truststore.
In order to register Agent A has to contact the Agent Name Server (ANS) which manages the IP-addresses of all agents. The ANS asks the Security Agent for the agent-certificate of Agent A and confirms the registration if the Security Agent has confirmed its validity. The Facilitator frequently asks the ANS if new agents have been registered and receives

the IP-addresses of the new agents. In this scenario the Facilitator gets aware of Agent A and asks the Security Agent for the valid agent-certificate of Agent A. Without this valid agent-certificate the Facilitator cannot contact Agent A by using a Secure Sockets Layer connection [8].
Now an already registered Agent B is looking for an agent with a specific ability. It asks the Facilitator for an agent with the required ability. Here, the answer is Agent A. Agent B receives the IP-address of Agent A from the ANS and the valid agent-certificate from the Security Agent. Because client/server-authentication is used for establishing a SSL-connection also Agent A needs to know Agent B´s agent-certificate. Therefore the Security Agent sends Agent B´s agent-certificate to Agent A which stores it in its truststore. Finally the SSL-connection between Agent B and Agent A can be established.

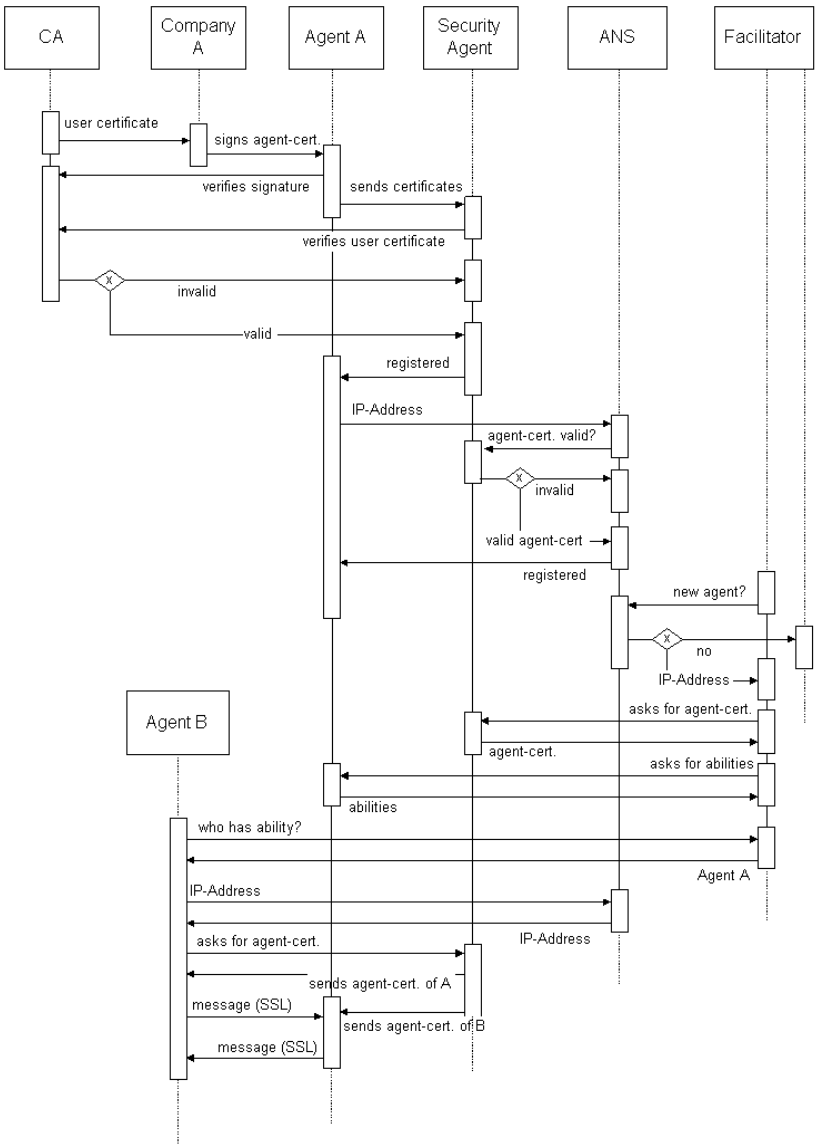

Fig. 5: Sequence diagram for registration and establishing contact (AUML)

The described communication acts are realized by extending the agent communication language: Several new performatives have been added.
For implementing the above described public key infrastructure the Java Secure Socket Extension (JSSE) and the cryptographic application programming interface by IAIK (Graz Technical University) have been used.

2.3.2 Procedure of submission and withdrawal on SiReAM

One of the demands of the VOB is, that contractors must be able to withdraw their tenders before the time-limit set for submitting has expired. Fig. 6 depicts the above mentioned procedures.

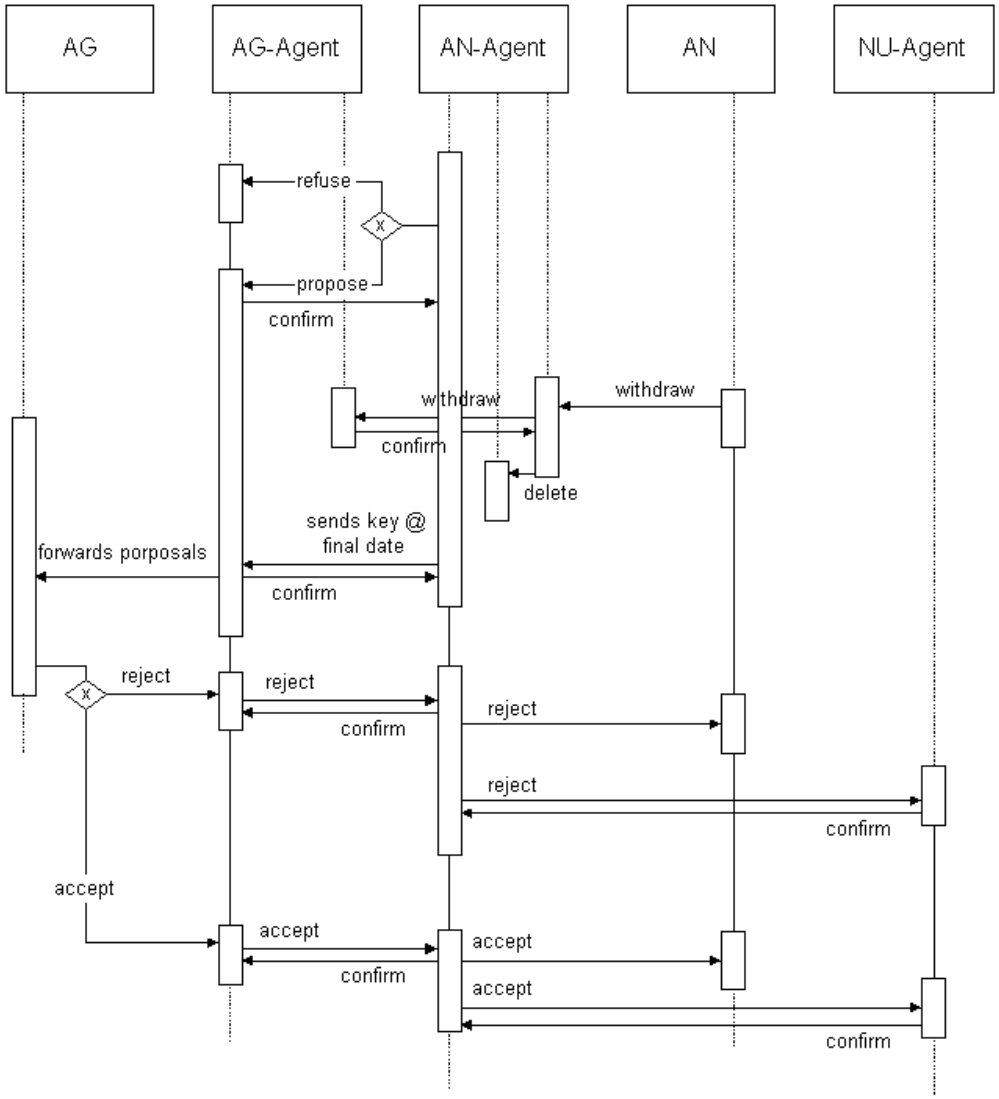

Fig. 6: Sequence diagram of submission and withdrawal (AUML)

2.4 LV Agent

The application LVAgent has been developed to provide access to the marketplace, to generate agents, and to control them [7]. A person who wants to take part in the marketplace has to log on the program either as an owner or as a contractor (or a subcontractor). According to the logging different user interfaces appear. For example an owner has the possibility to create new XML specifications for tenders by using the tool LVEditor (see Fig. 7)

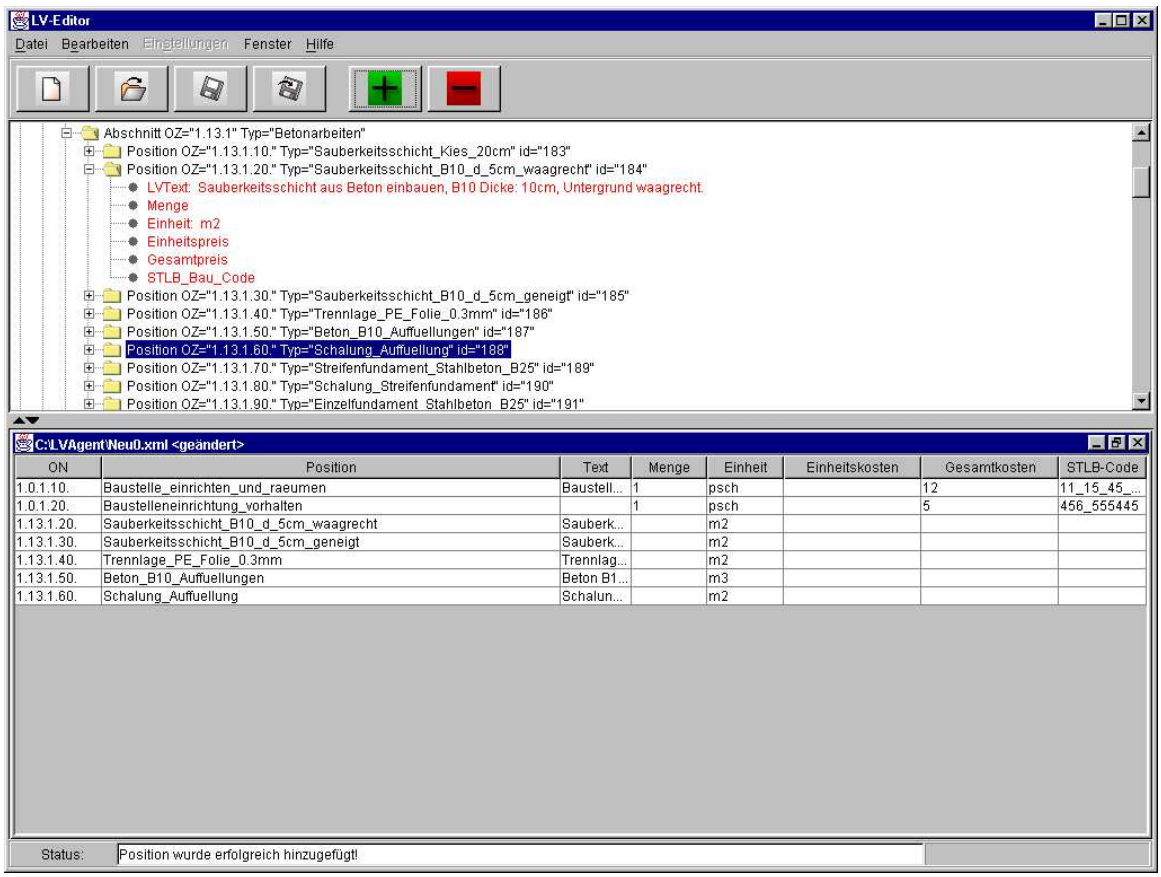

Fig. 7: LV Editor

After the specifications are created the owner generates his agent in consideration of these specifications. The agent automatically registers at the marketplace as described above. The agent's mailbox is monitored and contractors who submitted a proposal are listed separately (see Fig. 8).
The user interface for the contractor is depicted in Fig. 9. The agent is configured by highlighting the abilities in the upper window. After the agent is generated with the chosen abilities it also registers at the marketplace. Its communication is monitored in the user interface, too.

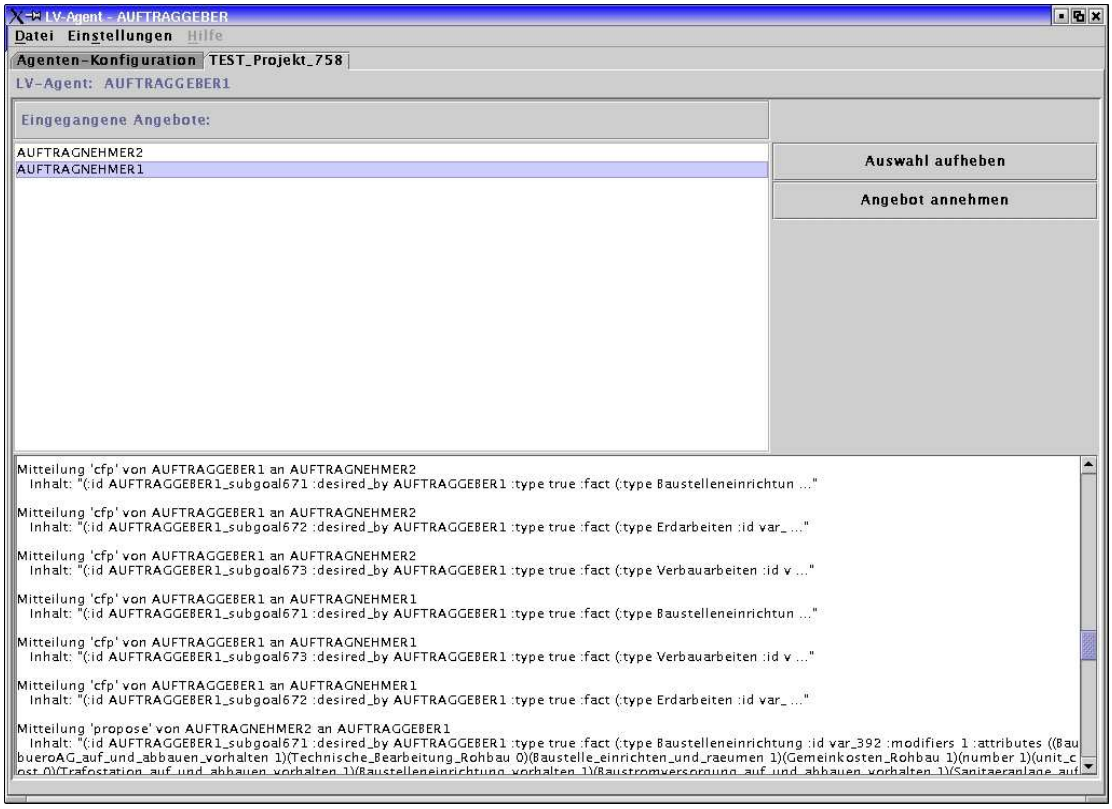

Fig. 8: LVAgent – Owner

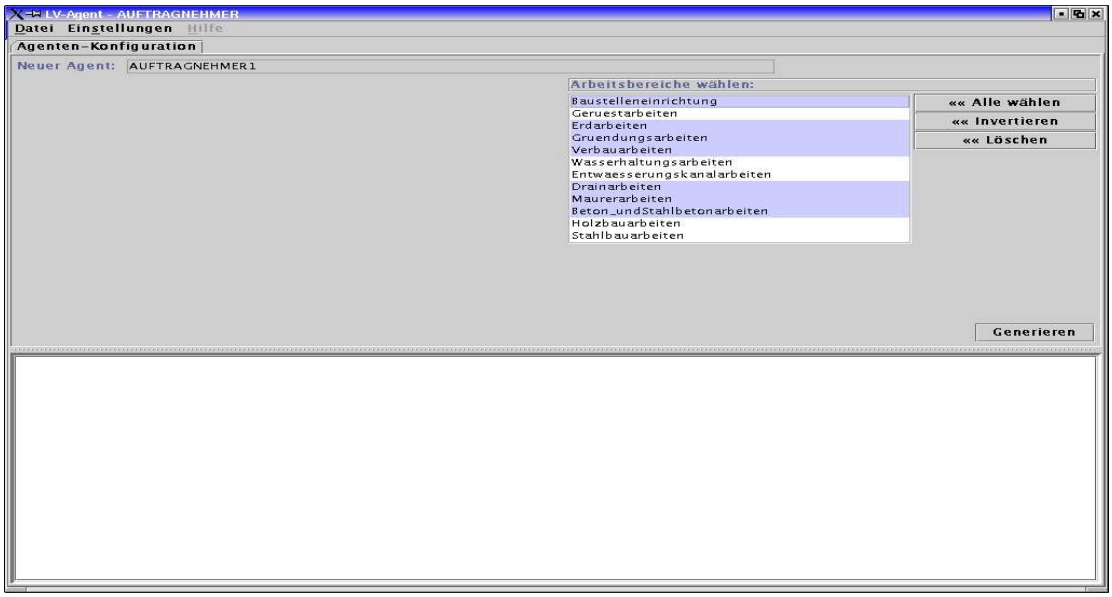

Fig. 9: LVAgent – Contractor

3 Summary

Comprising the advantages of an agent-based AEC-bidding procedure it can be pointed out that the bidding process is facilitated and accelerated. Due to the regular attendance of a company's agent on the marketplace companies can react faster and also more often to invitations to tender. Vice versa contracting authorities can reach more bidders in a relatively short period of time.
The present results prove that public tendering procedures regulated by the official contracting terms for the award of construction performance contracts can be integrated in multi-agent societies. A public key infrastructure for distributed agents has been developed so that secure transactions between software agents are made legal and binding.

4 References

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