A META-MODELING BASED SUPPORT FOR ADAPTIVE INTEGRATING IN AGENT-BASED SYSTEMS

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Abstract. Open agent architectures offer support for creating agent-based distributed software systems. These systems functionality results from the logical composition of a collaborating agents collection. This paper proposes a model for adaptive integration of agents in an open agent architecture. This model is based on meta-modelling at the support level and on negotiation at the agent level. Adaptive agent integration means that available functionality of an agent intended to join a distributed agent-based system is added to the global functionality after a negotiation process. The negotiation is realized by agents from the system and is based on the offered functionality features and on system global needs. The main advantage of adaptive integration is represented by the increased performance both in the agent space and at the entire system level, due to the active presence of, and only of, the required functionality subset of any agent.

Keywords: Meta-modelling, distributed agents systems, adaptive integration, negotiation.

1. INTRODUCTION

Collaborative distributed systems are one of the main research domain due to their possibility to capture distributed information interchange and process activity needed in many human activity domains. In order to facilitate human activity, these systems incorporate more and more functionality and also decision power. This results in agent-based distributed systems architectures.

Agent-based distributed systems need special middleware. This type of middleware have particular features that allow agents to publish their functionality and also to access other agents published functionality. These functionalities can be described using XML-based standards (Selim Aissi, Pallavi Malu, Krishnamurthy Srinivasan, 2002; WSDL, WSCL, WSEL, WSFL specifications, 2002; XLANG specifications, 2002), or using proprietary definitions. In most cases, these proprietary definitions are also XML-based.

Most of the existing frameworks are domain-oriented and Web-based. They define models for services definitions (WSDL) and models for activities choreography definitions (WSCL, WSCI, ebXML) as more services usage sequences. These frameworks also describe mechanisms for agent, as a collection of services, integrating.
An example is OAA presented by David L. Martin, Adam J. Cheyer, Douglas B. Moran (1998) and defined in OAA specifications, v2.2 (2002), a framework for software distributed systems building.

Such a system offer services realized by a collaborating autonomous agents collection. The main support component of the OAA is a service called “facilitator” responsible with inter-agent communication and cooperation in a transparent manner. This framework allows new agents to join the system. This results in extending system available functionality. A request to the functionality of the system is a complex “goal” and is realized using delegation. The middleware called “facilitator” delegates the components of the complex “goal” to the corresponding agents in the system. The client is not aware of the agents implied in the goal fulfilling.

2. ADAPTIVE INTEGRATION

Agents in collaborative distributed agent-based systems are the members of a society. This society can be extended by integrating new agents. There are at least three integrating models. The first model integrates new agents by creating them and providing them with a functionality defined by the society. The second model integrates new agents by extending the functionality of the society with the whole new agent functionality as in OAA specifications, v2.2 (2002). The third model, proposed in this paper, integrates new agents by integrating a part of the new agent offered functionality. In the context of the paper this is called adaptive integration and is realized in a negotiation process based on new agent offered features and agents society needs.

Adaptive integration has two essential requests. The request for integration needs meta-modeling-based flexibility. The request for adaptivity needs a negotiation mechanism based on three components.

The first component of the negotiation mechanism is the description of the integrating agent functional features.

The second component is the description of the system functional needs at the integration moment. It can be refined with system estimated future functional needs.

The third component is a distributed negotiation mechanism that generates decisions based on sets of functions described by the first two components. The negotiation mechanism is used by a privileged set of agents, which I call functionality brokers, and which have enough knowledge about the system in order to take a decision.

The negotiation process has three steps. In the first step the new agent makes its offer to the system. The offer contains functional specifications. In the second step the set of functionality brokers analyze the offer versus system needs and chooses those functions that are useful to the society. In the third step the agent gets the response and activates the services corresponding to the functions accepted by the society.

The main advantage of adaptive integration is represented by the increased performance of the whole system due to the reduced set of active services. Only the necessary services are active, resulting in better performance in the agent space. The necessary services are already active, resulting in better performance of the entire system.

3. SYSTEM ARCHITECTURE

The framework modeled here maps over a distributed architecture. The components of this architecture are the agents that offer services and the functionality brokers. The set of functionality brokers is also distributed, each broker being connected to a group of agents that offer related services. The request for integrating a new agent is broadcasted to the set of functionality brokers. When the agent is accepted it is attached to a corresponding group of agents, according to its accepted functionality.

The next figures contain the sequence of adaptive integration steps using the architectural representation of a significant part of the agents society.
In order to support runtime integration of a new agent in the system, the integration management module, composed of the collection of functionality brokers, must have access to a meta-model of the system functionality. The same meta-model is also used to determine, also at runtime, the actual set of system needs.

In a more refined vision, the global set of system needs can be determined at runtime too. In this case functionality brokers must have implemented a special characteristic that may be denoted as functional expertise of the domain. This functional expertise is used by the negotiation algorithm.

4. META-MODEL FOR ADAPTIVE INTEGRATION PROCESS

There are more different ways to represent models and meta-models for computing systems. OMG group defines a general object oriented meta-modelling facility MOF (Meta-modelling OMG specifications for MOF, XML, XMI, 2002).

In (C. Mindruță, 2003) is defined a formal meta-model, based on the theory of sets (N. Bourbaki, 1968), for collaborative distributed systems. Using this model, a distributed framework for dynamic development and collaborative applications execution is designed too. In this paper we extend the formal meta-model to adaptive integration process.

The adaptive integration process can be formally modeled as follows.

4.1 System structure model

Let \( A = \{A_1, \ldots, A_m\} \) be the set of agents that offer services to the clients of the system

This set is divided into subsets \( A^k \) according to a functional criteria \( c \).

Let \( C \) be the set of distinct values \( v^k \) for \( c \).

In this context, the sets \( A^k \) are defined as follows:

\[
A^k = \{A_i | A_i \in A \text{ and } c(A_i) = v^k\} \quad (4)
\]

and \( \forall k \neq m, A^k \cap A^m = \emptyset \)

Let \( A \) be the set of \( A^k \) sets of agents.

This definition introduces a one-to-one function

\[
a : A \rightarrow C \quad (5)
\]

\[
a(A^k) = v^k \quad (6)
\]

A new type of agent is associated to each \( A^k \).

The set of agents of this new type is denoted by \( FB = \{FB_1, \ldots, FB_n\} \) and represent the functionality brokers of the system.

This definition introduces another one-to-one function

\[
b : A \rightarrow FB \quad (7)
\]

\[
b(A^k) = FB_k \quad (8)
\]

4.2 Negotiation mechanism model

Let \( N \) be the set of system functional needs.

The functionality brokers negotiate integration based to the content of set \( N \), being aware of a part of the functions in the set. This is modeled with the function \( d \)

\[
d : FB \rightarrow P(N) \setminus \{\emptyset\} \quad (9)
\]

\[
d(FB_i) = N_i \text{ with } N_i \subseteq N \quad (10)
\]

Let \( F_{\text{new}} \) be the set of functional offer of the new agent.

The negotiation process is executed by the functionality brokers in the set \( FB \). Each \( FB_j \in FB \) manages a subset \( N_j \subseteq N \).

The functions of the new agent to be accepted are represented by the set \( F_{\text{new}} \cap N \). The selection can be refined according to performance criteria.

If

\[
F_{\text{new}} \cap N \neq \emptyset \quad (11)
\]

then \( A_{\text{new}} \) is accepted.
4.3 Integration of an accepted agent model

A\textsubscript{new} is accepted with a part of its functionality represented by the set $F\textsubscript{new} \cap N$.

The set $N$ changes each time a new agent is integrated and becomes

$$N^\sim = N \setminus F_{\text{new}}$$ (12)

Let $A^\sim_{\text{new}}$ be a new agent derived from the initial one and having only the accepted functionality denoted by $F^\sim_{\text{new}} = F_{\text{new}} \cap N$

The set of agents that offer services to the clients of the system becomes

$$A^\sim = A \cup A^\sim_{\text{new}}$$ (13)

$A^\sim_{\text{new}}$ is characterized by a value $v^\sim_{\text{new}}$ computed for the criteria $c$.

If

$$\exists A^k \mid v^\sim_{\text{new}} = v^k$$ (14)

then

$$A^k = A^k \cup \{A^\sim_{\text{new}}\}$$ (15)

If

$$\not\exists A^k \mid v^\sim_{\text{new}} = v^k$$ (16)

then a new set $A'^\sim_{\text{new}}$ is defined and a new $FB_{\text{new}}$ is attached to the set $FB$ so that

$$A^\sim = C \cup \{v'^\sim_{\text{new}}\}$$ (17)

$$A'^\sim_{\text{new}} = \{A'^\sim_{\text{new}}\}$$ (18)

$$FB^\sim = FB \cup \{FB_{\text{new}}\}$$ (19)

In conclusion, the adaptive integration model contains the sets $A, C, A, FB$ and $N$ for the system and the set $F_{\text{new}}$ for a new coming agent. It contains also the functions $a, b, c$ and $d$. Let $F$ be the set of new coming agents functionality sets; $F_{\text{new}} \in F$.

The corresponding meta-model is defined by the set $M_E$ of sets of entities and by the set $M_C$ of correspondences, where

$$M_E = \{A, C, A, FB, N, F\}$$ (20)

$$M_C = \{a, b, c, d\}$$ (21)

In order to support adaptive integration, a system must have access to its adaptive integration model and must implement an algorithm that manages this model in the manner presented above, in steps 2 and 3.

This meta-model allows system functionality extension according to a predefined set $N$ of system global needs. Because the set $N$ is also accessible part of the meta-model, dynamic extension of the global system needs is allowed too.

This simple model offers support for maximum flexibility in a multiagent evolving system.

5. CONCLUSIONS

This paper refers to the domain of distributed collaborative systems meta-modeling and proposes a simple mathematical model as support for flexibility, one of the main requests in distributed systems.

Flexibility has important consequences on performance in distributed collaborative systems. The performance is increased both for computing system and for the agents implied in a collaborative activity.

A system using this model in defining an agent integration service allows not only adaptive integration of a new agent but also can dynamically respond to new global functionality needs. This can be realized by requesting previous candidate agents, whose functionality was partially accepted, to activate another subset of their whole functionality.

A future development will extend the model with support for modeling non-functional needs and will define their role in the negotiation process.

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