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The models and algorithms for interaction of software agents

Abstract. In this paper software agents' communication models and algorithms in the virtual business environmenthave been proposed. They allow to reduce response time on any changes of environment imitating the innovation field due to increase of data exchange between the agents and reduction of general network load. Two mechanisms for conversion of inter-node agent communications to intra-node agent communications and dynamic agent distribution have been represented. Various implementation approaches for agent communication and interaction mechanisms have been considered. Methods for effectiveness increase of data exchange between mobile agents in the distributed system for information support of innovations have been proposed. Data exchange mechanisms between software agents in the virtual business environment based on agent address structure extension and using of middle-agents brokering and matchmaking services have been minutely described.

Key words: multi-agent system, agent communication models, data exchange algorithms, informationsupport of innovations.

Introduction

This article seems relevant to the task of creating a completely decentralized peer-to-peer systems for information support of innovations that allow flexible integration of existing and emerging information resources on innovation in a logically unified whole, thereby creating a single information space for effective interaction of subjects of innovation activities. Effective implementation technology of distributed information systems of this class is the technology of mobile program agents. Such systems shall provide not only distributed access to information, but also decentralized storage and data processing, to solve problems of technological and semantic heterogeneity of information resources a prototype of system of information support of innovative activities in the region – multi-agent system of integration of distributed information resources of innovations and appropriate information technology.

The article discusses the models and mechanisms for software agents' interaction of subjects of innovation activities in virtual business environment of innovations development, allowing reducing the agents' response time to environment changes that imitates the innovation field, by increasing the intensity of information exchange between the agents and reducing the overall load on the network. Methods of increase in efficiency of information exchange between mobile agents in distributed multi-agent system for information support of innovations are offered.

Problem definition

The technology of multi-agent systems (MAS) is a new paradigm in information technology, focused on sharing scientific and technological achievements and benefits of the ideas and methods of artificial intelligence (AI), modern local and global computer networks, distributed databases and distributed computing, hardware and software support means of the theory of distribution and openness.

Agent-oriented approach is widely used in various fields requiring the solution of complex distributed tasks, such as combined product design, reengineering of business processes and building a virtual enterprise, simulation of integrated production systems and electronic commerce, work organization of robots teams and distributed (combined) development of computer programs.

In case of internodal interaction of software agents in a virtual environment there is number of problems connected with increasing network load, decrease in intensity of information exchange between agents depending on speed and bandwidth of communication channels of the network, increase in messages delivery time and search time of required agent for interaction. As the solution for these problems the method is proposed which is based on splitting a common information space in which agents function into virtual platforms (the platform represents some separate network node) and moving intensively interacting agents to these platforms for the purpose of association of them in coalition. The proposed solution is realized in a form of two mutually complementing mechanisms (algorithms) of software agents' interaction: localization mechanism of inter-agent interactions (transformation of internodal agents' interaction into interaction in one common node) and mechanism of dynamic distribution of agents (distribution of loading between system nodes).

Mechanism of localization of inter-agent interactions

The mechanism of localization of inter-agent interactions consists of four phases: monitoring phase, phase of agents' distribution, phase of interaction (negotiation) and phase of migration of agents.

1.Monitoring phase. The Manager of Distribution of Agents (MDA) estimates intensity of internodal and intranodal communications of system agents by means of the system monitor and the manager of messages. MDA also uses information both on the agent-sender of each message, and on the node of the agent-receiver. MDA periodically calculates communication dependences $C_{ij}(t)$ in timepoint $t \in T = [t_1; t_2]$ between the agent i and the agents of j-node by the formula:

$$C_{ij} = \alpha(M_{ij}(t) / \sum_k M_{ik}(t)) + (1-\alpha)C_{ij}(t-1),$$

where:

M_{ij}(t) – number of messages sent by the agent i to the agents of j-node during period of $T=[t_1;t_2]$,

α – coefficient specifying the comparative importance of the new information in relation to outdated one and which is used for ignoring of temporary intensive interaction with the agents on a certain agent's platform. C_{ij}(t-1) is understood as value of the same communication dependence in the previous interval of time.

2. Phase of agents distribution. After a certain number of repetitions of monitoring phase MDA calculates a coefficient of communication dependence between the current node of the agent n and all the other nodes of the system. The coefficient of communication dependence R_{ij} between the agent i and the agents of j-node is determined by the formula:

$$R_{ij} = C_{ij} / C_{in}, j \neq n$$

When maximum value of coefficient of communication dependence of the agent is more than predetermined threshold θ, MDA of the current node includes the considered agent in the group of agents located in remote node of the system:

$$k = \arg_j \max(R_{ij}) \wedge (R_{ik} > \theta) \rightarrow \alpha_i \in G_k,$$

where: α_i is the agent i, $G_k k$ indicates a group of agents, and under $\arg_j$ hereinafter refers to an operation that returns the value of j, in which the ratio of communication depending R_{ij} takes the maximum value.

3. Interaction phase. Before moving the allocated group of the agents from node P1 to accepting node P2 the MDA of the node P1 interacts with MDA of the node P2. MDA of the node P2 veryfies current of the agents is carried out on the basis of communication dependences between the groups of the agents and the nodes of the system. Communication dependence D_{ij} between i-group of the agents and j-node of the system is defined on the basis of summation of communication dependences between all members of the group of the agents and the node of the system:

$$D_{ij}(t) = \sum_{k \in A_j} C_{kj}(t),$$

where:Ai is a set of indexes of all agents belonging to i-group of the agents, and C_{kj}(t) – communication dependence between k-agent and j-node in timepoint t. Group of the agents i^* which has the smallest dependence on the current node is selected by the following rule:

$$i^* = \arg_i \max(\sum_{j, j \neq n} D_{ij} / D_{in}),$$

where: n – number of the current node (agent platform).

The accepting j^* – agent platform of selected i-group of the agents is defined on the basis of communication dependence between i-group of the agents and j^* – node of the system as follows:

$$j^* = \arg_j \max(D_{ij}), j \neq n,$$

where: n – number of the current node.

Algorithms of information exchange between mobile agents

To improve the efficiency of distributed data processing by the agents and reduce the total amount of data transferred over the network, the existing algorithms of information exchange between mobile agents presented in (*Alouf et al.*, 2002), (*Stefano, Santoro*, 2002) were modified:

FMP (forwarding-based message passing – algorithm of readdressing of messages), FLAMP (forwarding and location address-based message passing – algorithm of readdressing and definition of the address of location of the agent), FLCMP (forwarding and location cache-based message passing – algorithm of readdressing and local caching for determination of location of the agent), ALMP (agent locating-based message passing – algorithm of localized exchange of messages between the agents) and ALLCMP (agent locating and location cache-based message passing – algorithm of localization and local caching for organization of exchange of messages between the agents). The proposed algorithms perform messages transfer directly from agents-senders to agents-receivers, minimizing a total quantity of hops at message transfer over the network. Results of experiments show that in case of intensive interaction of the agents FLCMP and ALLCMP mechanisms are more effective in respect of their performance than the others. However their efficiency significantly depends on extent of inter-agent interaction in the course of migrating of agents and groups of agents between the system nodes.

The mechanism of agent's communication based on use of intermediary agents

In open multi-agent systems characterized by high dynamism (new agents can appear and disappear at any moment and new nodes can be connected), each separate agent can't possess full information on all other agents in single information and communication space. In such environment of joint function the network services of intermediary agents (broker and entrepreneur services) are very effective for search of potential agents for interaction. Software agents can find other agents' names (by means of entrepreneur services) or send messages to other agents (by means of broker services), using their attributes such as methods, operating modes, characteristics or pseudonyms instead of their real names. For registration of agents' names in distributed environment the dedicated server of agents' names can be used.

Mediatorial functions of the agent are implemented in the form of separate component in his architecture, or can be realized in the form of independent customized application called the intermediary agent. Intermediary interaction between the agents includes either brokers, or entrepreneurs.

Brokers send the messages set by agents-senders to the network nodes with agents-receivers, whereas entrepreneurs only provide information on the agent-receiver's location requested by the agents intending to send messages. That is the final message is delivered by brokers to the agent-receiver, whereas entrepreneurs only help agents-senders to deliver messages to agents-receivers providing information on their location. Considering the number of hops at message transfer, we may draw a conclusion that broker services are more effective than entrepreneur ones as broker services usually require two hops at message transfer, and entrepreneur services – three.

With the use of common memory space called data fragments space which is run by the intermediary agent, the agents can register their attributes together with their names in this space, and also can communicate with each other with the help of information on agents' attributes taken from this data space. The Linda-model is the cornerstone of the most of developed intermediary agents (Carreiro, Gelernter, 1989). The structure of actor model of data fragments space (AMDF) is shown in fig.

The model allows software agents to use intermediary agents and the services they provide for search of "joint activity" agents, and it makes the basis of method of use of intermediary agents and their functions. At the same time the intermediary agent not only governs data fragments, but can also use both his own algorithms of search of "joint activity" agents, and algorithms provided by agents-initiators. This is the main difference of proposed method of use of intermediary agents and their functions in comparison with existing ways.

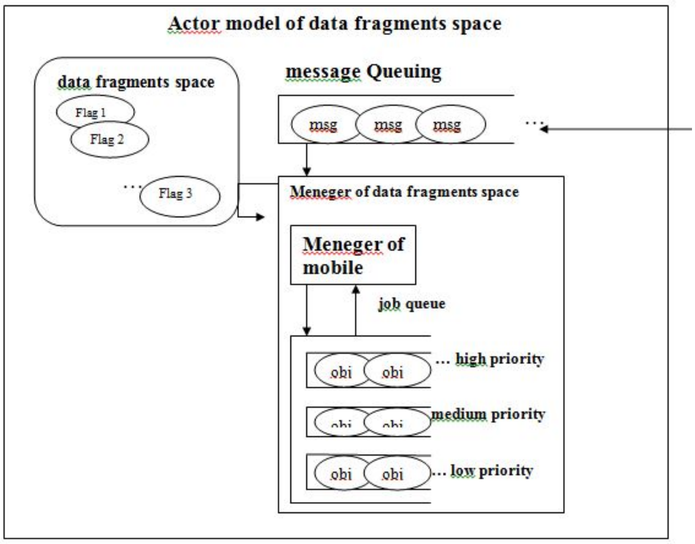

Figure –Structure of APFD

Conclusion

The article considers the separate agent-based mechanisms of functioning of the system of information support of innovations, and algorithms of organization of decentralized peer-to-peer communication between the nodes. Various approaches to implementation of mechanisms of communication of the agents are described. The existing models of communication of software agents are analyzed. Shortcomings of the considered models are revealed on which basis the approaches to increase in efficiency of interaction of mobile agents in distributed system of information support of innovations are offered.

On the basis of modification of existing models of inter-agent interaction the algorithms of information exchange between mobile agents allowing to increase efficiency of the distributed data processing by the agents and to reduce the total amount of the data transferred over the network are developed: 1) algorithm of agents communication based on the use of intermediary agents and their functions; 2) algorithms of information exchange between mobile agents based on local caching of information on the agent's location in the network and extension of address structure of the agent.

On the basis of the models developed during the researches and algorithms of interaction of software agents the method of minimization of internodal interactions in peer-to-peer problem-oriented distributed systems is offered. The method is based on clustering of software agents in semantic space presented in the form of conceptual domain model, and conversion of internodal interactions of the agents into intra-nodal ones. Implementation of the method provides reducing of load on communication infrastructure and increase in coefficient of accessibility of application services of software agents.

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