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In traditional business, negotiation is viewed as a long process, which has resulted in the development of computer methods to aid decision making.In recent years great effort has been invested in research and development of intelligent agents and multi-agent systems for automation of negotiation in supply chain management.The main task of multi-agent system is to link independently developed agents in a single system that allows collaboration and interaction between agents.That way you get much more efficient system for decision making in relation to the case of individual use of each of the agents.The aim of this paper is to highlight the positive effects that are achieved by the introduction of multi-agent technology in supply chain management.Application of multi-agent systems results in significant improvements in the field of communication and negotiation processes, costs reductions (expenditure of time and resources), customer satisfaction, supply chain efficiency,reduction of human work, inventory control, virtual poolingetc.

Keywords: supply chain management, agent technology, the negotiation mechanism, multi-agent systems, intelligent agents.

1. Introduction

The rapid development of products and a dynamic market require companies to reconstruct their functions and positions in the modern industry. In such circumstances, the companies will take appropriate actions to remain competitive in the global market. Concurrent engineering-CE is a productive way to survive in the global marketplace, it can be realized by simultaneous work of experts who have different functions within the company in order to produce specific products of high quality and functionality with minimum spending of time and resources *(Figure*1).The system of supply chain management is an effective approach to solve this complex situation.As an integrated network of suppliers, factories, warehouses, distribution centers and retail outlets, supply chain management system coordinates the processes in the entire logistics chain for faster and more flexible cooperation between companies, customers and suppliers.

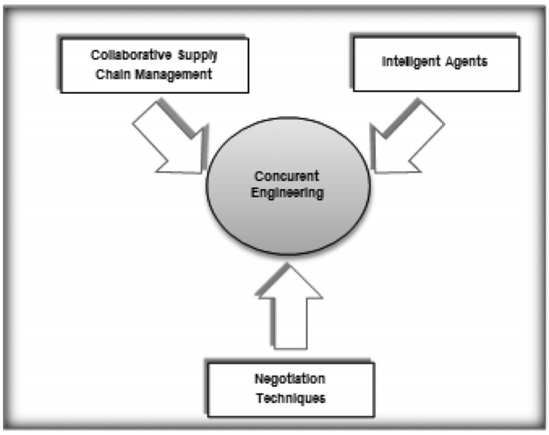


Figure 1: Assistants for CE realization (Ito & Salleh, 2000)

The cooperation of members in the supply chain management is a critical point in the implementation of effective supply chain;such implementation is not simple and cannot be efficiently performed using only conventional mechanisms of information exchange. Hence arise in business the new forms of collaboration and organization to facilitate joint work of suppliers and customers, to exceed the traditional type of organization within the linear supply chain to engage a large number of independent agents whose goal is a virtual association and formation of *time-sharing* resources. Such arrangements are described in the *adaptive value network* (AVN): "Arrangement in which companies have close relationships, working together as a system that provides customized products and services, achieve quality and in a responsible and coordinated ways adapt to the changing environment" (Makatsoris, Chang & Richards, 2004).

The emergence of agent technology initiates the development of new architectures and modeling software and supply chain management (Liang & Huang, 2006). Agent programming (Jennings, 2000) is defined as a software development paradigm that combines artificial intelligence and distributed systems. In fact, agent programming is a set of software components that are designated as agents - autonomous and proactive agents who are able to communicate with each other (Wooldridge & Jennings, 1995). The application of agent technology provides to distributed environment, effective communication, thus making it easier to integrate the entire supply chain into an independent echelon of connected systems. Activities in the supply chain such as procurement, planning, monitoring, enforcement, etc.., are represented by the software agent.Great effort has been made to establish agent and multi-agent systems in managing supply chains, especially for applications such as - manufacturing, planning, procurement (Shen&Norrie, 1999; Jennings, Norman, Faratin, O'Brien & Odgers, 2000; Leung, Wong &Sculli, 2006; Wong, Leung, Mark & Fung, 2006; Fang & Wong, 2010). In such systems, each agent operates on the basis of their internal models and the need to cooperate with other agents in the network. For example, an agent who represents the warehouse can immediately send stock availability to another agent who represents the customer in order to inform the customer about the availability of stock prior to ordering goods. This process in the business takes a lot of time even without the use of technologies.

2. Agent technology application

The term software agent is very popular in recent years. Public entities and private companies spend a considerable amount of time, effort and money for research - development and promotion of the idea of a software agent. It is rather surprising, because in essence, software agents are doing what is expected of an advanced computer program that is able to perform a specific task with a certain degree of autonomy (i.e. without permanent leadership and human intervention) in their environment. However, the real potential of this technology comes into play when you put together a number of software agents in the same environment. In such a case, a set of agents is viewed as multi-agent system where the agents are focused on each other and coordinate their activities so that you can avoid negative interactions with other agents and take advantage of their combined capacity.

The agent itself is a computer system that interacts with the environment, is capable of flexible and autonomous actions in dynamic and unpredictable multi-agent domains.Agents are autonomous software modules with the possibility perceptions and changing the state of the environment.The whole activity of an agent is related to the environment in which it is located, i.e. the environment is the source of its observation and the object of its actions.In the software sense, agents are typically implemented as examples of object-oriented classes, with appropriate identity, characteristics (attributes) and the rules of behavior (methods) - Figure 2.The behavior of agents can ultimately be reduced to a mapping of type perception action, where the mapping mechanism can be encoded in different ways: a simple table, logical rules (IF... THEN), or other techniques of decision making (neural networks, fuzzy logic), and similar (Žujović & Petrović (2005)). Coding (and therefore the decision-making process) determines the degree of agent's intelligence, which can range from simple reactive elements (type actions - response), to the complex structure of decision-making mechanism based on artificial intelligence techniques.

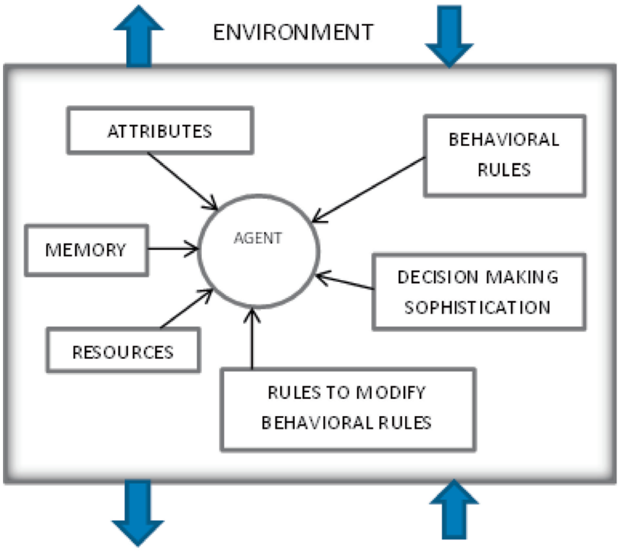
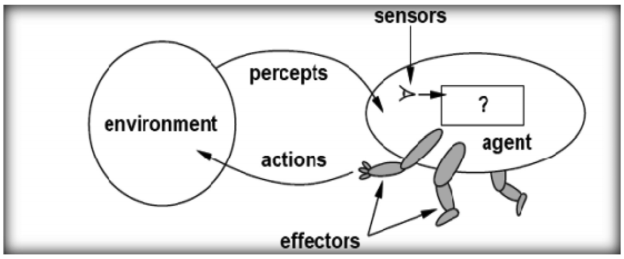


Figure 2: Schematic presentation of agent

For each agent one can observe the following elements(*Figure*3): 1) the environment - managing environment or the environment under which the sensors are working, 2) sensors - allowing agents to perceive the environment, 3) effectors - which respond to the perception.



AGENT=ARCHITECTURE+PROGRAM

Figure 3: Agent's features (Russel&Norning, 1995)

To perceive the environment the agent uses sensors to which the stimuli come from the environment.The information gathered by the agent during the observation sequences is stored in the memory of the agent.The actions that the agent is able to perform depend on the sequence of observations. A mapping function is responsible for efficient and effective response of the agent. The mapping function maps the list of perceptual sequences during the action of the agent, and on the basis of this the table is compiled in response to each sequence of observations.

The program whereby the agent functions is a function on the basis of which the perception mapping is done in the course of action.A program that is selected must be compatible with the architecture of the agent.The architecture of agents is a determined methodology for building agents; it determineshow the agent is decomposed into a series of modules and how these modules are connected.It is not only the structure of an agent but also shows the way in which modules perform their activities and link between the various agents.We cannot talk about the unique architecture of agents, but what it would be is dependent on the purpose of agents. Generally, the architecture of agents allows that the perception through the sensors be adjusted to the program, and to manage the program and pass the appropriate actions to effectors.

2.1. The importance of intelligent agents in the negotiation process

Often the term agent is used instead of the term intelligent agent - intelligence is defined as the presence of mechanisms of behavior aimed at solving a given goal.Due to the large amount of information that surrounds us in modern society, we need intelligent agents to enable efficient navigation.Intelligent agents (IA) are software that can automatically perform a task set to it by a person or other software (agent).When the agents are set once, they perform their tasks automatically, without further user intervention.These are most commonly used for automatic information search, for answering questions in the field of their knowledge, to inform users about interesting events (e.g. the emergence of a new article on the Internet, information on the possible occurrence of problems on the road between the initial and final destination, whether the given term appears somewhere on the web, etc..), for the current and personalized news, for intelligent decision-making process of users, to search the goods according to the criteria of most favorable price, for the provision of automated services such as checking of changes to web pages and the like.

The intelligent agent is defined as a program that aspires to the objectives and with minimal referrals, using intelligence or heuristic techniques.In addition to intelligence, the key features of intelligent agents are:
learning - from the user, other agents, from other sources
• collaboration - working with other agents to achieve their goal
• mobility - the mobility of agents in the network, the realization on different computers
• personalization - the knowledge of their users, their interests and preferences
• adaptability - learning from different sources, from the user's actions (Rudowsky, 2004).

These features facilitate the process of developing a complete system, helping to isolate the abstract and the irrelevant, and to focus on analysis and design of important characteristics of a particular problem (Garcia, Giret & Botti (2011)).

The role of IA is essential for successful communication process and negotiation between the company and suppliers; they provide us with relevant information to achieve objectives.The basis of negotiations is in reaching an agreement between the agents in providing services, and this approach has been used to manage conflicts that arise between the intelligent agents (Ito &Salleh, 2000).IA start with negotiations after defining the communication objectives, and end by making certain decisions during the process of using different strategies and techniques to generate the initial offer.They have a high degree of self-determination and decide alone when, where and under what circumstances the actions will be performed.The interaction of agents can be directed to any particular action, change of the planned course of action and agreement on a common course of action.Interactions between agents enable rationalization and integration of the entire process of cooperation in the management of supply chains.

Figure 4 represents participants in the life cycle of negotiation: 1) the analyst and owner: describing and formalizing objectives, 2) designer: forming plans for achieving the goals of the agents through interactions, 3) implementer: implementing a designed strategy by using respective protocols and tools for achieving the goals. In the first step in the life cycle of negotiation, the negotiation analysis suggests the need to acquire and model the individual settings for protocol and negotiation strategy. The negotiation mechanism of the agent negotiation must have an adequate strategy and negotiation protocol (Fang& Wong, 2010; Chen, Peng, Finin,Labrou& Cost). Negotiation protocol is used to organize messages between agents, determine the flow and format of messages between the negotiating parties.On the other hand, the strategy of negotiating is a way in which negotiating party acts in order to achieve the best outcome of negotiation (e.g. what to assign - what you keep), so the strategy for each participant is personal.In the next step, designers tend to define strategies and protocols that will enable the achievement of objectives.In the final step, implementers are looking for group commitment through the communication exchange.IA work on behalf of their participants, and they have specific skills to manipulate other members according to their assignment using the plan and protocol of negotiation.When IA negotiates, it discovers its goals to the other members, identifies conflicts,seek solutions to conflicts and concentrates on finding the ideal solution for achieving its goals.

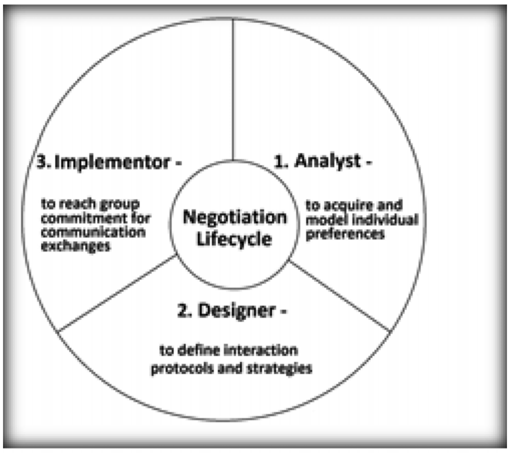


Figure 4: Life cycle phases of negotiationsand participants in it (Ito &Salleh, 2000)

2.2. Evolution of multi-agent systems

The systems in which multiple agents work together to execute a task or solve ommon problem are called multi-agent systems (MAS).MAS represent an information echnology that is rapidly developing as a result of agent technology, i.e.autonomous oftware modules that represent real-world objects.Such a system is in fact a broad networkof software agents that collaborate to solve problems that are beyond the individual capacities or knowledge of any classical way of solving problems.Such systems are ideal for modeling problems for which there are several different methods for solving and multiple perspectives.In systems builtin this way, instead of a control agent managing the process, the management is divided into several agents which, according to their specialties, assume responsibility in controlling the complex process.Using multi-agent system increases the overall security of the system in situations of cancellation of one of the agents, or the entire system can be automatically reconstructed or stopped in a controlled way.

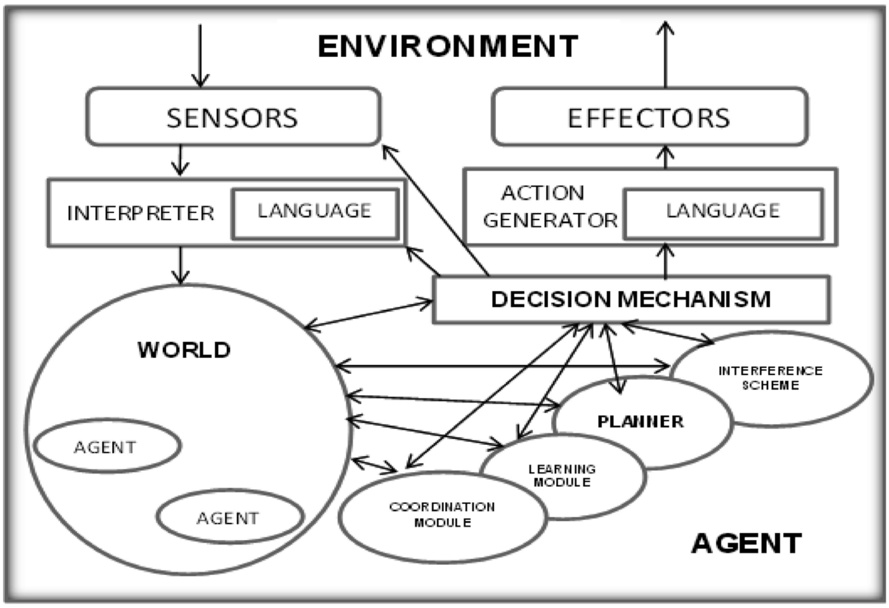


Figure 5: Architecture of agents: Components of agents in multi-agent systems

In such systems only the elements of the system are explicitly modeled, while the dynamics of the entire system is left to itself, i.e.it will arise spontaneously from the interaction of its own elements. Systems composed of agents consistently follow the system definition - a collection of elements in mutual interaction (Figure 5). This significantly facilitates the process of modeling, because the behavior of elements in most cases can be described precisely, whereas the behavior of the system is often so complex that it is impossible to express it in a formalized form. The overall aim of MAS is to create a system that specifically interconnects agents and to allow the ensemble to function without the possibility of any individual adjustments (Ren & Anumba, 2003).

The conceptual basis of MAS is given in the theory of complex systems whose rules are not explicitly defined, and there is no centralized element that governs the global dynamics (Zujovic & Petrovic, 2005). According to this definition of the MAS we can exclude those systems where there is a central planner or designer that controls the decision-making processes of local agents.In other words, the MAS is defined as a completely decentralized system. Therefore, only systems that enable meaningful interaction between agents can be classified as true MAS.

MAS attracted great attention of experts from many different scientific fields, both in nature and in the social sciences. The growing interest in this type of networking occurs because of the possibility to ensure efficiency in solving problems in which the data, expertise and control are distributed. When designing MAS it is necessary to define the number of agents, a critical amount of time to perform the task, the dynamics of the arrival of the goals, communication costs, cost of failure, the impact of users, and the uncertainty of the environment. At the level of each agent the following should be defined: the initial state of the domain, the possible actions of other agents and the output actions of the agents.

Multi-agent systems attempt to solve the whole problem by mutual cooperation and thus give a better answer to complex problems. This paper demonstrates how agent technology enables us to solve communication relationships in the distribution environment. Multi-agent simulations do not provide a solution to all problems, nor do they necessarily make a replacement for the classic techniques of modeling and simulation. Instead, they should be treated as a complementary approach to conventional models, which are used when conventional techniques cannot give the desired results.

2.3. Application of MAS in SCM

Supply chain is a network that includes all the elements involved in materials transformation into a finished product and transporting it to the end user.Managing the supply chain becomes especially complex if it is based on outsourced functions which cover almost all activities from production, to sales and distribution.Such a situation introduces uncertainty into the business and results in delicate business relations, to be held and managed effectively. Therefore, MAS is trying to solve the whole problem by agents' collaboration. As members of a supply chain the software agents are engaged in automating the buyer-seller negotiations in the supply chains management (Kersten& Lo, 2003, Braun et al 2006). In this way, MAS can assist in solving complex problems and making decisions or support the people to decide.Agents are especially suitable for coordination in supply chains due to the following characteristics:

- Information, resources and control over data and resources are essentially distributed (Jenssen, 2004)
- The supply chain is adaptive and changes over time. Agents should serve as unifiers of components of supply chain management which is owned by the particular entity in the supply chain (Julka, Karimi&Srinivasan, 2002).

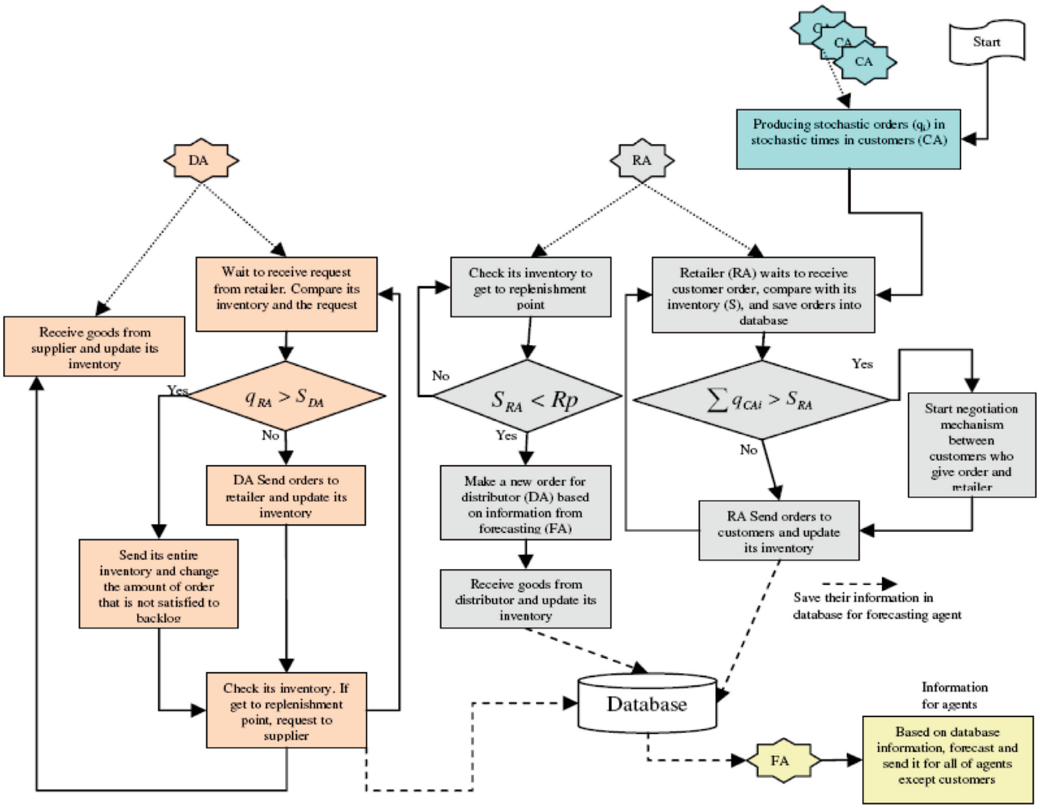


Figure 6: Schematic presentation of agents in SCM (Saberi and Charalampos, 2008)

The company is required to quickly and effectively respond to the order to meet customer requirements.However, an unexpected rush of orders causes delays in delivery and reduces efficiency.It is clear that to solve such problems one should develop a mechanism such as the MAS, which integrates various functions.In multi-agent environments, autonomous agents need to interact with one another to achieve their goals because reciprocal dependencies exist among them. In this context, negotiation is a fundamental tool to reach agreements among agents with conflictive goals in both competitive and collaborative scenarios (Monteserin & Amandi (2011)).

The proposed algorithm (Figure 6) demonstrates the concept of virtual markets and facilitates supply chain management in a dynamic environment.Although collaboration is a basic characteristic of virtual market (due to the changing environment and autonomous / heterogeneous nature of the members of the virtual market), it can only succeed if activities are properly managed in the supply chain.A schematic model follows the behavior of each individual agent (DA-agent distributor, RA- agent seller, CA-agent customer, FA-agent for the forecasting).It is evident that there is one database, which can be accessed by all the agents.Furthermore, agent for forecasting processes this information and forwards it to the agent seller and agent distributor.

3. Effects of applying intelligent agents and multi-agent systems

Technologies of intelligent agents and multi-agent systems represent one of the most promising directions for the development of a system based on the Internet and knowledge in logistics.Intelligent agents represent the organization within the logistics domain models and their logistics functions, processes, expertise and interaction with other organizations (Graudina&Grundspenkis, 2005).

MAS is currently used as an efficient way to solve a wide range of problems (Vallejo, Albusac, Mateos, Glez-Morcillo & Jimenez (2010)), in the field of planning, real-time control, robotics and many other industrial areas.Expansion of the use of MAS-based model of software engineering (Jennings, 2000) is based on: the use of autonomous agents that solve complex and distributed problems, use of language (Bordin et al., 2006), or even making standards (Foundation for Intelligent Agents Physical, 2002).In other words, Agent programming is used to design a problem in cases where other approaches are insufficient and incomplete.

The reasons for the introduction of IA and MAS in commercial systems are as follows:
- introducing this type of technology enables performance of various tasks such as making decisions, solving various problems that normally require the human intelligence, such as problem diagnosis, data classification, planning and negotiation;
- identify critical information with the input of resources, monitor and take action based on the information context (information sharing, forecasting knowledge and use of the negotiating mechanisms);
- autonomously collect duties on behalf of users, this kind of programming does not require constant user intervention. Reduce human work by using the automated agents which act on behalf of the users. Spare the user from having to find, negotiate, and in general deal with buyers and sellers.
- such systems connect separate agents and create ensemble of functions that is beyond the capacity of any individual agent.This ensemble provides flexibility in the conduct of affairs, and is more efficient for solving complex problems;
- promote cooperation between members of the supply chain, although the interaction between the IA can lead to conflict and coalition.Negotiation techniques are used to overcome conflicts and coalitions in order to achieve agreement between agents rather than persuasion to accept the already existing solution.Negotiation is the core of many agent interactions;
- virtual pooling (virtual market concept) and *time-sharing* resources.

The positive effects achieved by the introduction of IA and the MAS:

- successful process of communication and negotiation between manufacturers and suppliers, creates good communication networks that allow the satisfaction of customer requirements.MAS are inexpensive standardized communication infrastructure, which includes separate agents that interact in an open and *real-time* environment and provide transaction security;
- increases supply chain efficiency - integration and coordination of various systems and processes in the supply chain, facilitating the supply chains management in a dynamic environment.

- achieve an efficient flow of materials and total costs reduction - reduced consumptions of time and resources, the agents are faster than humans, using the automated agents can save the transportation and communication costs that human contact may incur (Linlan, Haigang, Xueguang & Hong (2011))
- reduction of the *bullwhip* effect – reduces oscillations of user requirements and improves the forecast level of reserves and resources. Thus it determines the above demand and reduces the total operating costs.
- inventory control is enabled (e.g., an agent who represents the warehouse can stock availability information to other agents in order to know the stock availability at any time)
- provide answers to uncertain market, merger and division of competence risk.
- increase the security of the system in situations of failure of one of the agents.
- such networks, regardless of the state, are always active and ready to respond.

A significant advantage in applying multi-agent model is in that it can be constructed even if the legality of the behavior of the whole is unknown (entire system). Multi-agent simulation capabilities are higher compared to conventional simulation models, and are used to express more complex dynamics and structure. Agents in multi-agent simulation models are heterogeneous and thus enable a more realistic view. Also, these models are generally easier to maintain, because all of the updates are made to the level of individuals - agents. Elements of multi-agent simulations are relatively faithful copies of objects from the real domain, which considerably facilitates communication between policy simulations (programmers) and end-users (experts in the subject area).

Conslusion

The area of autonomous agents and multi-agent systems is very diverse and represents an area that is rapidly expanding.It is a combination of several scientific fields such as distributed processing, object-oriented systems, software engineering, artificial intelligence, economics, sociology, organizational science. The methodology of the program based on agents provides a range of effective tools and techniques that have the potential to significantly improve the technique of software ranging from conceptual design through to actual implementation. During the past two decades a significant number of improvements is evident in design and implementation of autonomous agents and how they interact.

Multi-agent systems introduce a new approach to modeling, which is reflected in the specific relationship between global and local (and elements of the system). Modelling is reduced to explicitly defining the elements of the system, while the dynamics of the entire system arises spontaneously from the interactions of the components.This significantly facilitates the process of modeling, because the behavior of elements in most cases can be described precisely, whereas the behavior of the system is often so complex that it is impossible to express it in a formalized form.

Agent technology has offered a powerful repertoire of tools and techniques that have the potential to significantly improve the way people conceptualize and implement many types of software.Agent technology is gaining in importance and it is used to solve real problems, and commercial applications.Agents are used in a growing, wide variety of applications - from small comparative systems, such as personalized*e-mail*filters to large, complex systems such as *air-traffic control.*Natural and simple is that so many different applications can be represented by agents, and that is what best explains why researchers and developers are impressed by the given approach potentials (Saberi &Makatsoris (2008)).

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