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ABSTRACT

Automation of inter-organizational cooperation and negotiation in supply networks with dynamic information flow needs intelligent software with a capacity for adaptation. The aim of this paper is to propose a multi-agent architecture for cooperation and negotiation in supply networks (MCNSN), which incorporates a learning capability for agents, and discusses the issues which need to be addressed for coordination of buyers and sellers, both at a transaction and an organizational level, as well as the broader issues of cooperation and negotiation. Certain agents use case-based reasoning (CBR) as a framework for learning the best strategy between buyers and suppliers. MCNSN operates at two levels. The first is a transaction/enterprise level which requires dynamic customer relationship management (CRM) information, user profiling and will eventually need a bargaining capability. The second is at a logistics/manufacturing level which deals with product transfer and requires learning cost-effective buyer/supplier dealings for specific products.

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Keywords

Intelligent agent, case-based reasoning, supply chain management, cooperation, negotiation, supply networks..

INTRODUCTION

With the rapid growth of the Internet and Web, a global internet economy has emerged. High levels of connectivity and the dynamic flow of information between companies has changed the traditional view of the "linear" supply chain into a supply network (or demand network) with multiple sources and destinations. This is increasingly putting pressure on companies to quickly and accurately evaluate new market opportunities and other strategic business decisions in coordination and negotiation with potential partners in supply networks. An interesting example is given by Brereton (2003) of software service engineering for providing software functionality over the web, which may require dynamic supply chain redesign in selecting a specific mix of web services (Adomavicius and Tuzhilin 2001).

In this paper, we propose and describe a multiagent architecture for cooperation and negotiation in supply networks (MCNSN), which incorporates a learning capability for some agents and discusses the issues which need to be addressed for coordination, cooperation and negotiation. Certain agents use CBR to pursue the best learning strategy between buyers and suppliers while other learning approaches may be better for other aspects of cooperation. MCNSN operates at two levels of cooperation/negotiation. The first is a transaction/enterprise level which requires dynamic CRM information, user profiling and will eventually need a bargaining capability. The second is a logistics/manufacturing level which deals with product transfer and requires learning cost-effective buyer/supplier dealings for specific products.

The paper is organized as follows. The next section relates the current work to prior research. This is followed by a short discussion of the move from supply chains to supply and demand networks. The issue of cooperation and negotiation between parties the supply network in the MCNSN system is described and is followed by details on the multi-agent architecture and the role of each agent type. The concluding section discusses the architecture and further research directions.

RELATIONSHIP TO PRIOR RESEARCH

Multiagent technology has been used for planning, management and scheduling of supply chains, although most related work is intra-organizational rather than inter-organizational. Bussman and Schild (2000) describe work done at Daimler-Chrysler for an approach that flexibly adapts to changing production conditions. Resources are allocated dynamically by a continuous coordination and negotiation process among the relevant agents and every machine agent uses a virtual buffer to control the machine and material through the machine. Early research in this area was done by Beck and Fox (1994). They use a mediating agent which has a global perspective and gathers information on commitments from other agents when there is any event disrupting supply. More recent work (Fox et al. 2000) proposes an agent based framework which simulates the supply chain with agents at each station. Huhns and Stephens (2001) describe a multiagent system where each agent manages a part of the B2B supply chain for the company. Sycara and Zeng (1999) describe an agent-based approach to optimizing an inventory model under cost and lead-time constraints. The AARIA project (Baker et al. 1997; Baker et al. 1999; Parunak, Baker et al. 2001) is a DARPA project which investigated the role of agents in supply chain management (SCM). MASCOT (Sadeh-Koniecpol et al. 2001) is a multiagent system (MAS) for dynamic information processing in supply chains where each agent uses a blackboard architecture for coordination and control and an agenda to drive activity. Eschenbacher et al. (2000) describe a multiagent approach to a demand chain. The earlier approaches tended to focus on static knowledge and known relationships. The current research is attempting to deal with dynamic information and learn how to deal with relationships.

Although the multiagent approach in SCM has received considerable attention, a number of unresolved questions remain in cooperation and negotiation in supply networks (Schneider and Perry 2001). Of particular interest in the current research is the structure of agents needed to deal with dynamic information. One of the key issues in agent intelligence is dynamic learning. Several learning approaches have been considered in MAS e.g. reinforcement learning (Arai et al. 2000) and neural networks (Wermter et al. 2000). This research proposes using case-based reasoning (CBR) as a learning paradigm so that agents can learn and respond dynamically to changes in the supply network.

CBR has been used in a variety of intra-organizational scheduling problems, particularly for reactive scheduling where there is a need to adapt schedules due to some event disturbing the production cycle (Dorn 1996; Cunningham and Smyth 1996). However, scheduling over the entire supply network does not appear to have had much attention. Corchado et al. (2001) also use CBR to allow agents to re-plan their intentions in real time based on the BDI (Belief-Desires-Intentions) framework. Olivia et al. (1999) propose the use of CBR for BDI agents for intelligent search on the web. Finnie and Sun (2003) have considered a MAS in which only those agents that require learning have CBR capability. The current research builds on this work using a variety of learning techniques including CBR..

FROM SUPPLY CHAINS TO SUPPLY/DEMAND NETWORKS

Electronic communication between organizations has for many years been constrained by a traditional EDI/X12 framework which has required each partner to work closely to ensure system compatibility. More recently, several initiatives (e.g. eCo System (Glushko et al. 1999), RosettaNet (www.Rosettanet.org)) have advanced the use of XML as a common business language for suitable communication.

The phrase supply chain implies links in a linear form, looking from the retailer to distribution to transportation to manufacturing. Virtually universal connectivity and dynamic information flow has changed the supply chain to a supply network capable of rapid change as the need arises. The supply network integrates the value chain and the supply chain, and extends them into a complete graph-formed value-supply network (Sun and Finnie 2004). The focus has also changed from a supply-side view of optimizing production efficiency to a demand–side view of consumers driving the process. Silisque et al. (2003) state that supply chains will develop into demand networks that adapt to consumer demand in almost real time.

In an electronic business environment, information flows at high speed and organizations must be capable of rapid reaction and reorganization in response to dynamic information relating to any changes in constraints or conditions (McClellan 2003). In what follows, we describe a multiagent-based approach for intelligent automation of inter-organizational interaction in the supply network.

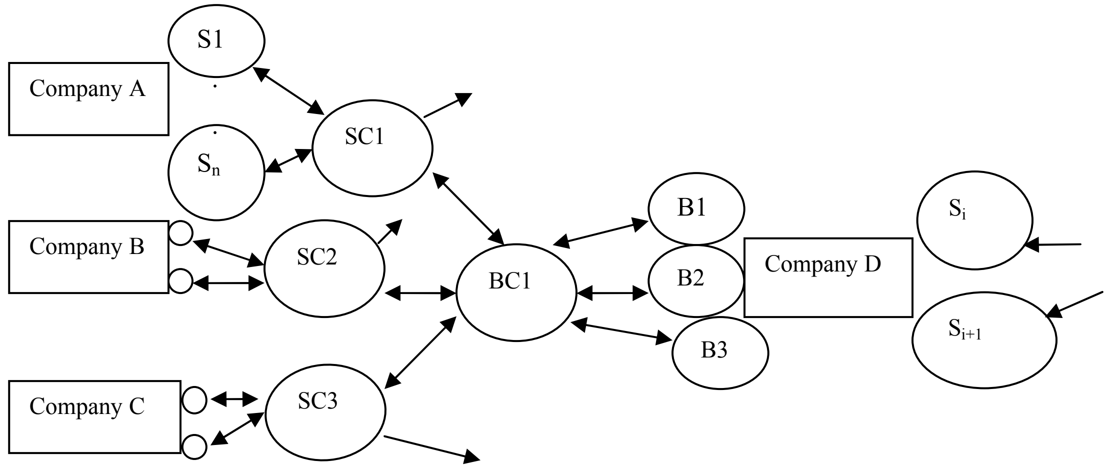

Figure 1: Multi-agent cooperation and negotiation in a supply network

COOPERATION AND NEGOTIATION IN SUPPLY NETWORKS

In a supply network there is a continuous process of planning, scheduling and management of supply and demand which requires cooperation, coordination and negotiation by human managers. However, delegating these responsibilities to an agent requires a great deal of autonomy and intelligence. In this paper we consider a CBR perspective for a possible solution.

Any organization will have some history of dealing with problems relating to orders and perturbations in the supply network and the solutions applied, as well as some formal processes for dealing with these. In order to automate the response to any stochastic event, the supply network system must be capable of reacting as one would expect a human agent to do. In many cases, a human agent responds by working from and possibly adapting solutions to previously encountered situations similar to the present problem i.e. a process of reasoning from prior cases or Case-Based Reasoning (CBR) (Finnie and Sun 2003).

CBR has been primarily used in scheduling as an aid to creating and adapting specific schedules inside the organization (e.g. Dorn 1995). In MCNSN (Figure 1), CBR is used for at least some of the intelligence at the buyer/supplier junctions within a specific supply network. A number of *buyer agents* control the interface between an organization and its suppliers, with each of the buyer agents using CBR to provide intelligent processing of supply needs on the basis of prior experience.

A *buyer manager (control agent)* coordinates and controls the activation and operation of the buyer agents utilizing CBR. It also uses CBR to select a suitable strategy for finding all components required for a particular product i.e. it will review or revise the bill of materials, decide on suitable suppliers and set up agents to control the interaction with each supply agent.

It should be noted that there is one buyer manager agent for each organization. It will also have responsibility for ensuring that all components are suitably sourced i.e. a failure procedure must be in place to backtrack if a specific supplier fails to ensure supply.

A *seller (supplier) agent* is at the supplier interface, and is responsible for each product type. A request to purchase from an organization may itself trigger *adaptations* in the internal schedule for that organization and in turn cause its buyer agents to *negotiate* with its suppliers. To *coordinate* the actions of supplier agents there is a supplier manager (control) agent for each supplier. This has responsibility for checking whether the product can be supplied. Each order that is processed for a specific customer forms part of the *case base* for that customer and provides a historical portrait of the relationship with the customer. This is part of the customer relationship management (CRM) function and used to dynamically adapt the customer profile.

In any real world scenario there will be a number of reasons, hard and soft, which define why buyers may deal with certain suppliers and vice versa. Over time, suppliers would become trusted and specific arrangements made to deal with them. This type of soft relationship is difficult to automate. However, the buyer and supplier control agents have the responsibility for selecting a specific set of suppliers or buyers to deal with. The sources of information for this decision can be static or dynamic and hard or soft. Specific priorities or contractual preferences can be imbedded here and adjusted over time with dynamic information if necessary. It is highly unlikely that a purely automated system would be able to handle the subtle nuances of all commercial relationships, but it is feasible to combine both aspects in one system.

CBR-based Cooperation in Supply Network

Cooperation is an important characteristic of supply networks (Schneider and Perry 2001). An agent with "perfect" knowledge and "complete" capabilities for a given task has no need to require the cooperation of other agents. However, normal agents do not have "perfect" knowledge and "complete" capabilities for a given task.

One approach to CBR-based cooperation is described by Martín et al. (1999). A cooperation mode establishes how two agents must behave to accomplish a particular task. Two cooperation modes between CBR agents were proposed in that research: Distributed CBR (DistCBR) and Collective CBR (ColCBR). The DistCBR cooperation mode is a class of cooperation protocols where a CBR agent[1] is able to ask one or several other CBR agents to solve a problem on its behalf, and the ColCBR cooperation mode is a class of cooperation protocols where a CBR agent is able to send a specific CBR method to one or several CBR agents that are capable of using that method with their case base to solve the task at hand (Plaza et al. 1997). Therefore, the DistCBR cooperation mode enables an agent to share experiential knowledge acquired by an acquaintance by means of particular problem solving methods, while the ColCBR cooperation mode allows a couple of CBR agents to share experiential knowledge.

CBR-based Negotiation in Supply Networks

Automated negotiation has had relatively little support to date because of the complexity of the negotiation process, which depends on the complexity of the product or service being negotiated. The approaches to negotiation in supply networks can be classified into two classes: a cooperative approach and a competitive approach (Guttman 1998). Competitive negotiation takes place if there is at least a conflict of interests between the buyer and seller/supplier. Consequently, there will be the minimum collaboration necessary between buyer and supplier to solve the negotiation problem, while cooperative negotiation tries to get as much collaboration as possible between the two parties. However, both approaches present two extremes on a continuum of possible underlying problems. In practice, a negotiation usually lies between cooperative negotiation and competitive negotiation.

In the automated supply network, buyer agents search for a product that meets their demands. The goal of a CBR-based negotiation system is to identify these demands in cooperation with the supplier agents and to find a product that fulfils them (Sun and Finnie 2004, p.186). During negotiation, the CBR-based negotiation system might suggest or even add some new demands or modify some weak demands for the purpose of finding an appropriate product. For configurable products, it is also possible for the CBR-based negotiation system to modify existing products during product adaptation to meet the customer's demands. Therefore, the task for the CBR-based negotiation system during the negotiation process is the combination of *iterative demand adaptation* and *iterative supply (product) adaptation*. The former is realized by making proposals for adding or changing the demands from the buyer agent, while the latter is done by supply/product adaptation with the goal of finding an agreement point in the multidimensional demand/product space (Sun and Finnie 2004, p. 186).

An intelligent agent should be able to negotiate with the customer agents and to assist them during the search for an appropriate product in the supply network. The buyer and supplier manager agents use CBR technology to negotiate; that is, they assess the similarity of the current negotiation to previous negotiation cases in their negotiation case base. Once a negotiation case is selected as the most relevant to the current negotiation, the agent might revise or adapt this case in order to meet any count-offer from the counterpart. Successful negotiation cases are kept in the case base for reuse in later negotiation case retrieval. These agents can use fuzzy rule-based adaptation to adapt the most similar negotiation case to the current negotiation situation (Sun and Finnie 2004, p. 207).

A MULTIAGENT ARCHITECTURE FOR COOPERATION AND NEGOTIATION IN A SUPPLY/DEMAND NETWORK

Based on the above discussion, we propose a multiagent architecture for cooperation and negotiation in supply networks (MCNSN), as shown in Figure 1, in which S_i are supplier agents, SCi are supplier manager agents, Bi are buyer (or procurement) agents, and BC1 is the buyer manager agent for company D. Each buyer agent has a local case base. Buyer and seller manager agents need more intelligence and have their own company case base. The supplier agents will check on the impact of an order i.e. can it be realistically scheduled and processed? This may in turn generate a procurement need, causing a spreading activation of agents. Agents will also need to have fall back positions i.e. if there is no suitable information in the

[1] In the context of this paper, a CBR agent represents any intelligent agent with CBR ability. For example, a buyer agent, buyer manager agent and supplier manager agent all are CBR agents (see earlier discussion in Section 3).

case base, there must still be a response – either by appealing for human intervention or going to other forms of reasoning e.g. rule-based.

MCNSN provides two levels of agent operation: the buyer/supplier manager agents at the enterprise level and the buyer/supplier agents at the logistics level. At the enterprise level, the agents are "middle agents" (Decker at al, 1997) which "support the flow of information in electronic commerce, assisting in locating and connecting the ultimate information provider with the ultimate information requester." At the logistics level, the supplier manager agents and buyer manager agents deal with product transfer and require learning cost-effective buyer/supplier dealings for specific products. With increasingly intelligent capability in these agents, it can be expected that bargaining and negotiation will be required as the process becomes increasingly automated. Ontañon and Plaza (2001, 2002) use a CBR approach where each agent learns individually and learns when to cooperate to improve performance.

Buyer Agents in MCNSN

Buyer agents in MCNSN control the interface between an organization and its suppliers. Each of the buyer agents provides intelligent processing of supply needs on the basis of prior experience. In the multiagent architecture, the cycle of buyer agents is:

1. an order is received and the buyer manager agent selects a product based buyer agent to process it.
2. The case base for this agent is checked for previous suppliers of the product.
3. A message is broadcast to the "web" looking for prospective suppliers. This assumes a standardized structure to define suppliers.
4. Prospective suppliers are ordered in terms of some priority scheme and a recommendation made to the buyer manager agents.
5. The manager agent will decide that either:
    - the order is sent to the supplier or
    - there is a call for quotes.

Supplier Agents in MCNSN

A supplier manager agent in MCNSN receives a request for an order or a quote for a specific product and needs to initiate a process to determine if and when the order could be filled. This may require rescheduling of production and ordering of new inputs. Each supplier manager agent maintains a history of prior dealings with buyers.

The supplier manager agent has the following options:

1. Decline the order or quote.
2. Agree to fill the order/quote without adjusting existing schedules.
3. Revise schedules on a priority basis to meet an order or estimate impact if a quote is required. In this case a supplier (watch) agent is initiated to monitor the progress.

Suppliers have the task of getting themselves known so that buyer agents can find them. A variety of existing mechanisms can be considered e.g. marketplaces or search engine positioning..

Agent Interaction in MCNSN

As noted above, interaction between buyers and suppliers occurs at two levels in MCNSN. At the buyer agent and supplier agent level (B_i, S_i), the interaction is product based with the focus on logistics/manufacturing. Buyer agents need to keep their production optimal while supplier agents need to determine the impact of rescheduling.

At the supplier and buyer manager agent level (BC_i, SC_i), the interaction is inter-enterprise with the focus at the trading level. Both buyer manager agents and supplier manager agents are concerned about maintaining a good trading relationship to mutual benefit. For the buyer manager agent this may mean retaining a range of alternative suppliers. For the supplier manager agent, this is customer relationship management (CRM). The supplier agent needs to have information on the likely impact of rescheduling which it can feed into the CRM process so that any negative effects on a customer are minimized. In essence, this is using dynamic information for real-time CRM. Obviously in many cases this will only be part of the total picture and for some time to come will probably still require human intervention if any concerns are flagged. However the need to incorporate the capability to gather and process dynamic information is obviously an issue that will need to be part of CRM, particularly in a virtual enterprise environment. Each order that is processed for a specific customer forms part of the case base for that customer and provides a historical portrait of the relationship with the customer.

Much of the research on building user profiles could be of value in this area (Bradley 2000). Most work on profiling has been related to personalizing the customer experience i.e. providing content or services to meet customer needs on the basis of their preferences and behavior, using either collaborative-filtering or a content-based approach. However, the fundamental principle remains one of building a picture of the customer – in CRM that profile can also be used to customize a response. Adomavicius and Tuzhilin (2001) describe an interesting approach which uses data mining to analyze information based on customer transaction history. The use of CBR has been investigated in profiling (Smyth and McGinty 2002). The WEBSELL system (Cunningham et al. 1999) uses a CBR approach to develop individual profiles for customer interaction. Bradley et al. (2001) have applied it in personalization for on-line recruitment. We are investigating its potential to facilitate dynamic CRM as part of the current research.

Agent Learning in MCNSN

The role of cases and the need for learning is fairly easily defined for buyer agents in MCNSN. Each buyer agent deals with orders for a specific product with a range of possible suppliers. Its role is to select the best supplier option (although the concept of "best" may have different meanings e.g. a better price may have supply inefficiencies or quality control problems).

As a test of the buyer agent's ability to learn from prior cases, a simple simulation of a specific scenario was developed with three suppliers of a specific product to select the best buyer (Finnie and Barker, 2004). Each supplier had well defined supply characteristics in terms of probable delays and costs. The buyer case base (BCB) simply recorded information on order size, order time (in days), previous delays and a price for the order product. If a case is judged to be sufficiently different from any case in the BCB, it will be added to the BCB. If it is reasonably similar to an existing case, the existing case had its price for the order adjusted. In a simulation of 500 cases, the system rapidly learnt the best supplier. When conditions are changed to favor a different supplier, it adjusted quickly to work primarily with the lower cost supplier. When a new supplier entered the market with a better price/delivery combination, this became the preferred supplier over time. Although much of the early work in this field focused on cost as the only driver in transactions, more recently it has become accepted that there is a need to take a range of factors into consideration (McKay and Marshall 2004).

On the supplier side the learning is less well defined. Suppliers in MCNSN evaluate buyers but not from the sense of selecting the best one. A supplier would like to react to any change in scheduled orders in the most profitable way possible which means that learning essentially becomes a process of establishing priorities. Factors such as order size, order frequency and customer loyalty need to be taken into account.

In a simplistic view of buyer/supplier relationships, a buyer would always seek the most profitable deal, which might include paying as late as possible and reducing supplier profit margins to the minimum. However, as McKay and Marshall (2004) note, ".. instead of adversarial relationships with supply chain participants, more cooperative relationships in which win-win outcomes are negotiated for all concerned make much more business sense in the long term." This means that any automation of the negotiation and cooperation process must include a range of factors, both qualitative and quantitative. An autonomous agent must have the capability of reasoning with and comparing a range of factors. CBR offers a learning mechanism that can include a number of attributes to improve understanding of a relationship between a buyer and a supplier.

CONCLUSIONS

To use dynamic information efficiently in inter-enterprise supply network management, decisions will need to be made automatically and effectively. The multiagent system approach proposed in this paper provides a suitable architecture for rapid and agile response to any event. MCNSN is scalable as there is no overall controller – each organization in the chain or network will have its own agent management structure.

An agent in MCNSN must be capable of intelligent reasoning and learning. The CBR approach provides at least part of the intelligence, and is capable of learning dynamically e.g. as a new case is encountered it will be added to the case base for that specific product in a specific company. CBR has the potential to be used a variety of roles in this system e.g. in CRM personalization, for negotiation and for supplier selection.

The MCNSN system proposed here requires further development and testing both in simulated and real environments. Although initial results are encouraging for the determination of a suitable supplier, the structure of supplier agents, their relationship to CRM, the use of profiling and the development of negotiating capability needs to be explored. The approach is limited in its capability of handling some of the more subtle issues in supplier/buyer relationships, such as the issues of trust and preferred suppliers. Other learning methods must also be considered as an option e.g. it appears as if forms of reinforcement learning may be more suitable for aspects of the supplier control agent's learning.

REFERENCES

1. Adomavicius G. and Tuzhilin, A. (2001) Using Data Mining Methods to Build Customer Profiles. IEEE Computer, 34, 2, 74-82.
2. Arai, S., Sycara, K., and Payne, T. (2000) Multi-agent reinforcement learning for planning and scheduling multiple goals. *Proc 4th Int Conf on Multiagent Systems*, July, Boston, MA, USA, pp. 359 - 360.
3. Baker, A. D., Parunak, H.V.D., and Erol, K. (1999) Agents and the Internet: Infrastructure for Mass Customization, *IEEE Internet Computing* 3, 5, 62-69.
4. Beck, J. C. and Fox M.S. (1994) Supply Chain Coordination via Mediated Constraint Relaxation. *Proc 1st Canadian Workshop on Distributed Artificial Intelligenc*e, Banff, AB.
5. Bradley, K., Rafter, R. and Smyth, B. (2000) Case-Based User Profiling for Content Personalisation. *Proc Int Conf on Adaptive Hypermedia and Adaptive Web-based Systems* (AH2000), Trento, Italy.
6. Brereton, P. (2003) The Software Customer/Supplier Relationship. *Communications of the ACM*, 47, 2, 77-81.
7. Bussman, S. and Schild, K. (2000) Self-Organizing Manufacturing Control: An Industrial Application of Agent Technology, *Proc 4th Int Conf on Multi-Agent Systems,* Boston, MA, USA.
8. Corchado, J. M. (2001). CBR-BDI Agents for an E-commerce Environment. *Advances in Business Solutions*. T. M. Salamanca, Spain, Catedral Publicaciones.
9. Cunningham, P., Bergmann, R., Schmitt, S., Traphöner, R., Breen, S., and Smyth, B. (2001) WEBSELL: Intelligent Sales Assistants for the World Wide Web. KI -- Zeitschrift für Künstliche Intelligenz , Issue 1, 28-32
10. Cunningham, P. and B. Smyth (1996) Case-Based Reasoning in Scheduling: Reusing Solution Components, *Int J Production Research* 35, 11, 2947-2961.
11. Decker, K., Sycara,K. and Williamson,M. (1997) "Middle-Agents for the Internet " Proc 15th Int Joint Conf on Artificial Intelligence.
12. Dorn, J. (1995) Iterative Improvement Methods for Knowledge-based Scheduling, *AI Communications* 8, 8, 20-34.
13. Finnie, G. and Barker, J. (2004) Adaptive Agents For Supply Networks, *Proc 6th Int Conf on Enterprise Information Systems (ICEIS 2004)*, Porto - Portugal , April 14-17.
14. Finnie, G. and Sun, Z. (2003) A knowledge-based model of multiagent CBR systems. *Proc. Int Conf on Intelligent Agents, Web Technologies, and Internet Commerce (IAWTIC'2003)*, Vienna, Austria.
15. Fox, M.S., Barbuceanu, M. and Teigen, R. (2000) Agent-Oriented Supply-Chain Management, *Int J Flexible Manufacturing Systems* 12, 165-188.
16. Glushko, R.J., Tenenbaum, J.M. and Meltzer, B. (1999) An XML Framework for Agent-Based E-commerce, *Communications of the ACM,* 42, 3, 106-114.
17. Guttman R.H., Moukas, A.G. and Maes, P. (1998) Agent-mentioned electronic commerce: A survey, *Knowledge Engineering Review*, 13, 2, 147-159, URL: http://ecommerce.media.mit.edu.
18. Huhns, M.N. and Stephens, L.M. (2001) Automating Supply Chains, *IEEE Internet Computing*, 5, 4, 90-93.
19. Kalakota, R. and Whinston, A.B. (1997) *Electronic Commerce: A manager guide*. Reasing, Massachusetts: Addisson-Wesley Longman, Inc.
20. Martín, F.J., Plaza, E. and Arcos, J.L. (1999) Knowledge and experience reuse through communication among competent (peer) agents, *Int J of Software Engineering and Knowledge Engineering*, 9, 3, 319-341.
21. McClellan, M. (2003) Collaborative Manufacturing: Using Real-Time Information to Support the Supply Chain, Boca Raton, St Lucie Press.
22. McKay, J. and Marshall, P. (2004) *Strategic Management of e-Business*, John Wiley and Sons, Australia.
23. Olivia, C., Chang, C.F., Enguix, C.F. and Ghose, A. (1999). Case-Based BDI Agents: An Effective Approach for Intelligent Search on the World Wide Web. *Intelligent Agents in Cyberspace*, AAAI Press, Menlo Park CA.

24. Ontañon, S. and Plaza E. (2001) Learning when to collaborate among learning agents, *Machine Learning: ECML* Springer-Verlag.
25. Ontañon, S. and Plaza E. (2002). A bartering approach to improve multiagent learning. *1st Int Conf on Autonomous Agents and Multiagent Systems (AAMAS-02)*, Bologna, Italy.
26. Parunak, H.V.D., Baker, A.D., and Clark S.J. (2001) The AARIA Agent Architecture: From Manufacturing Requirements to Agent-Based System Design, *Integrated Computer-Aided Engineering*, 8, 1, 45-58.
27. Plaza, E., Arcos, J.L. and Martin, F. (1997) Cooperative case-based reasoning. In: *Distributed Artificial Intelligence meets Machine Learning*, *LNAI 1221*, Springer Verlag, pp 180-201.
28. Sadeh-Koniecpol, N., Hildum, D., Kjenstad, D., Tseng, A. (2001) MASCOT: An Agent-Based Architecture for Dynamic Supply Chain Creation and Coordination in the Internet Economy, *Production Planning & Control,* 12, 3.
29. Schneider, G.P. and Perry, J.T. (2001) Electronic Commerce, Course Technology, Canada.
30. Silisque, A., Brito, I., Almirall, E., Cortés, U. (2003) From Supply Chains to Demand Networks. Agents in Retailing: *The Electrical Bazaar Artificial Intelligence Research Report*, LSI-03-41-R, URL: www.lsi.upc.es/dept/techreps/html/R03-41.html
31. Smyth, B. and McGinty, L. (2002) The Route to Personalization: A Case-Based Reasoning Perspective. *J. Expert Update*, 5, 2, 27-36. The British Computer Society Specialist Group on Artificial Intelligence (BCS-SGAI).
32. Sun, Z. and Finnie, G. (2004) Intelligent Techniques in E-Commerce: A Case-based reasoning perspective, Heidelberg, Springer.
33. Turban, E., Lee, J., King, D. and Chung, H.M. (2000) *Electronic Commerce, A Managerial Perspective*, Upper Saddle River, HJ: Prentice Hall.
34. Wermter, S., Arevian, G. and Panchev, C. (2000) Towards hybrid neural learning internet agents. In: Wermter, S. and Sun, R. (eds) *Hybrid Neural Systems,* Springer, pp 158-174.