MODELLING COLLABORATIVE FORECASTING IN DECENTRALIZED SUPPLY CHAIN NETWORKS WITH A MULTIAGENT SYSTEM

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Keywords: Collaborative forecasting, Multiagent system, Supply chain management, Decentralized decision-making process.

Abstract: Information technology has become a strong modelling approach to support the complexities involved in a process. One example of this technology is the multiagent system which, from a decentralized supply chain configuration perspective, supports the information sharing processes that any of its node will be able to carry out to support its process in a collaborative manner, for example, the forecasting process. Therefore, this paper presents a novel collaborative forecasting model in supply chain networks by considering a multiagent system modelling approach. The hypothesis presented herein is that by collaborating in the information exchange process, less errors are made in the forecasting process.

1 INTRODUCTION

The development of supply chains increasingly addresses the establishment of relationships among the participating firms, companies or nodes, generally in the manufacturing and logistic process. Therefore, in order to carry on a collaborative forecasting process in the supply chain, Aviv (2001) considers that each member is not only able to jointly maintain a single forecasting process in the system, but is also capable of integrating this joint forecasting process into its individual replenishment process. In fact, the collaborative forecasting process applies supply chain management concepts to the forecasting process and uses available information and technology to force a shift from independent, forecasted demand to dependent, known demand (Rodriguez et al., 2008). Moreover, Poler et al. (2008) based the collaborative forecasting process on the fact that each interrelated company had relevant information available to forecast what the rest did not have. This scenario facilitates the implementation of the collaboration model and the progressive spreading across non-collaborative firms.

Moreover, information fields can be used as the basis for coordinating an organization, which can be seen as a collective agent composed of other individual collective agents that may encompass multiple embedded information fields (Filipe, 2003).

In this same supply chain forecasting context, Liang and Huang (2006) establish that two types of agents may be employed to respond to the various types of services to support a forecasting process, for example, control and demand forecast agents. Thus, the multiagent-based modelling approach was the tool selected to support decentralized collaborative forecasting in the supply chain networks proposal.

Therefore, this paper has been set out as follows: firstly, the decentralized supply chain agent-based model under a collaborative context is presented by considering Hernández et al. (2008) modelling methodology. Then, the simulation results of a particular model are briefly presented. Finally, the main conclusion and a brief description of our future work are presented.

E. Hernández J., Poler R. and Mula J. (2009).
MODELLING COLLABORATIVE FORECASTING IN DECENTRALIZED SUPPLY CHAIN NETWORKS WITH A MULTIAGENT SYSTEM.
In *Proceedings of the 11th International Conference on Enterprise Information Systems - Artificial Intelligence and Decision Support Systems*, pages 372-375
DOI: 10.5220/0002008503720375

2 SUPPLY CHAIN AGENT-BASED MODEL

2.1 The Collaborative Forecasting Process in a Decentralized Supply Chain. Generic Model Formulation

Collaborative forecasting firstly considers a demand pattern (real demand) within a period length of $T > 1$. Then according to a decentralized perspective, each node in this forecasting process is able to identify two kinds of partners or nodes with which it will become involved in the forecasting process (Figure 2 shows an example of a generic and complex supply chain network configuration which will be used to support the following decentralized collaborative forecasting agent model and the experiments.).

Therefore, a generic supply chain network is defined by interconnected Y supply chains (SC). Thus, the total number of supply chains is defined by SC_Y given the fact that $Y \geq 1$. Then, $\forall SC_Y$ and for all the nodes in which the forecasting process is going to take place, the collaborative nodes are firstly identified. This characteristic means that this type of nodes will send the demand plan related to certain products and periods. Finally, it is necessary to identify non-collaborative nodes to obtain firm orders which will be classically forecasted.

Thus by considering the distributed supply chain network made up of K nodes, where $K \in SC_Y / K > 1$, a total of NC nodes is considered to be collaborative, and a total of NNC is considered non-collaborative. Therefore, we allow CN_β^t to be defined as the demand from the collaborative node β in period t where $t > T$, and NCN_δ^t is the firm order for the non-collaborative node δ in period t where $1 \leq t \leq T \wedge 1 \leq \delta \leq NNC$. In addition, the total sum of the demand plans considers a number of periods which is the equivalent to the minimal common interval among the demand plans. Therefore, by considering P_β to be the number of periods of each β node, it is possible to define $MINF$ as these minimal forecasted periods, where $MINF = \min(P_\beta)$, given the fact that $1 \leq \beta \leq NC$. With this in mind, and also from a generic viewpoint of the proposed model, the first term, the collaborative forecasting component (CFC), is composed of the information exchanged among the NC nodes which, from a matrix perspective, can be defined as follows (Eq. 1):

$$CFC \Rightarrow \begin{bmatrix} \sum_{\beta=1}^{NC} CN_\beta^{T+1} \\ \vdots \\ \sum_{j=1}^{NC} CN_\beta^{MINF} \end{bmatrix}, \forall \beta, Y / \beta \in SC_Y \quad (1)$$

Along these lines, each component of Eq. 1, represents the total sum of the common period in relation to each collaborative node until term MINF is defined. With the second term however (Eq. 2), which represents the non-collaborative information exchange process, a classical forecasting process is considered (to make the explanation of the process easier), as is the exponential smoothing of the real demand RD_t involved in the t periods (where $1 \leq t \leq T$); in this case, a τ factor is considered to take over the forecasting fix factor regarded in the real forecast. This factor is between 0 and 1 and is also called the smoothing constant. Thus, by defining NCN_δ^S as the forecasted demand in relation to the real demand for each period and node, where $1 \leq S \leq T$, the forecasted demand value for the next $T+1$ period for each t and δ is defined as follows (Eq. 2):

$$NCN_\delta^S = \begin{cases} RD_{S,} & \forall \delta, Y / \delta \in SC_Y / S = 1 \\ NCN_\delta^{S-1} + \tau \times \left(RD_{S-1} - NCN_\delta^{S-1}\right), & \forall \delta, Y / \delta \in SC_Y / 2 \leq S \leq T+1 \\ NCN_\delta^{S-1}, & \forall \delta, Y / \delta \in SC_Y / S > T+1 \end{cases} \quad (2)$$

Therefore, given the collaborative forecasting in the already defined descentralized supply chain, the final matrix expression, which defines collaborative forecasting (by considering the collaborative and non-collaborative aspects) for the next $T+1$ periods, is defined as follows (Eq. 3):

$$\begin{bmatrix} \sum_{\delta=1}^{NCN} NCN_\delta^{T+1} & + & \sum_{\beta=1}^{NC} CN_\beta^{T+1} \\ & \vdots & \\ \sum_{\delta=1}^{NCN} NCN_\delta^{T+MINF} & + & \sum_{\beta=1}^{NC} CN_\beta^{T+MINF} \end{bmatrix} \quad (3)$$

2.2 The Collaborative Forecasting Agent-based Model

The agent-based model that supports collaborative forecasting in decentralized supply chain networks mainly considers two aspects. First, the related agents involved in the process and, second, the behaviour that each of them are able to recognize in order to carry out their activities. As it is also assumed that agents are self-interested, they will participate for the purpose of obtaining the most precise forecasting process by sharing their demand plans (collaborative nodes) and by providing firm orders (non-collaborative nodes)

Therefore from a generic point of view, the agents to be considered in the collaborative forecasting process are described as follows:

- **Forecasting Agent:** this agent carries out the forecasting process. In terms of the decentralized environment where the agents are involved, and depending on the particular case, this agent is able to obtain its forecast and may also behave as a (collaborative or non-collaborative) customer in order to send information to the other agents. Thus, the forecasting agent is able to detect whether information comes from a collaborative node, or not. With these facts in mind, it will sum the demand plans or will apply a classical forecasting process.
- **Collaborative Agent:** this agent exchanges its demand plans, and is collaborative. In that sense, this agent generates its demand plans or sends them to the corresponding forecasting agents. Thus, the information generated for this agent is assumed to support a mid- or long-term decision-making process.
- **Non-Collaborative Agent:** this agent contemplates the facts by considering its needs, and only sends a short-term information horizon with certain frequency which may be known or not. Therefore, it is feasible to say that this agent represents the uncertainty of the environment

In addition, the communication process (see Figure 1) among the agents is supported by behaviours that are oriented to generate demand and firm orders, to develop the forecasting calculus, to identify the collaborative or non-collaborative agents, and to send and receive the corresponding messages. All this is done by considering the FIPA standard communication protocols.

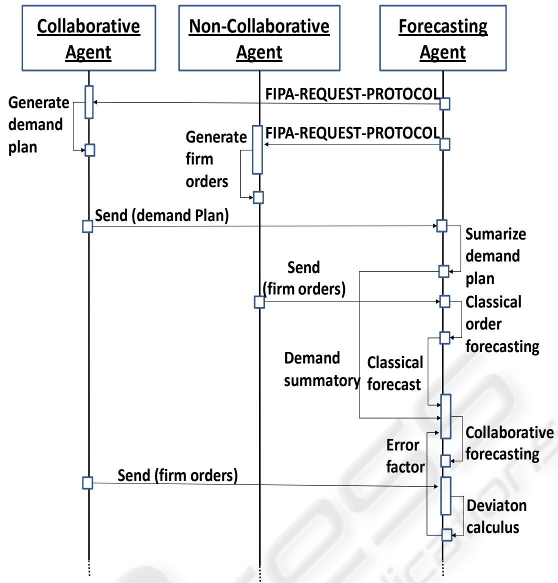

Figure 1: A collaborative agent-based forecasting process.

2.3 Impact Analysis of the Proposed Model

Regarding collaboration at upper levels, information is considered to support the decisional process to better match the nodes' requirements. Then the next lower levels will make their decision by considering the information and constraints from the next upper level.

3 EXPERIMENTS

The experiments carried out in this paper consider the specific case shown in Figure 2. Thus eight nodes have been considered (N1, N12, N13, N14, N15, N17, N31and N32), and have been assumed to be geographically distributed and belong to different supply chains.

Nine main scenarios (Table 1) have been defined to show the impact of collaborative forecasting on the deviation of the forecasted data compared with the real demand pattern (Figure 1). These nine scenarios (S1, S2, S3, S4, S5, S6, S7, S8 and S9) compare the results by increasing the collaboration level (by increasing the number of β nodes and by decreasing the number of δ nodes).

In addition, and in order to support decentralized collaborative forecasting, each supply chain that makes up the supply chain network is related to its own container which is managed by the main JADE container.

3.1 Main Results and Discussions

Therefore with the simulated agent-based model, the results (Table 1) aim to highlight the forecasting deviaton in terms of the collaborative configuration which has been assigned to differents nodes. In Figure 2, these are the instantiated classes that carry out the ACLMESSAGES.

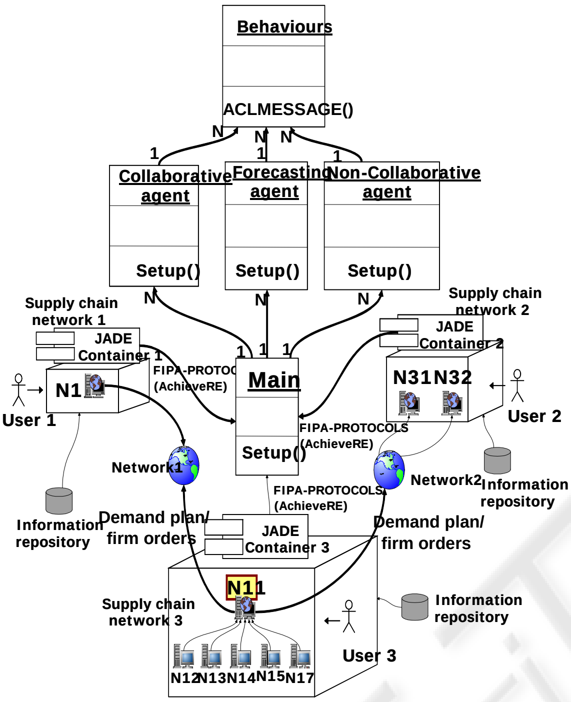

Figure 2: Particular decentralized supply chain network agent-based model (a UML-based model approach).

According to Table 1, a clear impact caused by increasing the collaborative level has been observed in the forecasting deviation.

Table 1: Deviation of the forecasted demand.

Periods	TOTAL real orders	Collaborative level						
		S9 (100%)	S8 (88%)	S7 (75%)	S6 (63%)	S5 (50%)	S2 (13%)	S1 (0%)
61	**112**	-1	-14,2	-28	-44,4	-44	-55,4	-41,8
62	**85**	-3	-12,2	-19	-12,4	-8	-22,4	-14,8
63	**88**	4	-11,2	-11	-19,4	-23	-22,4	-17,8
64	**82**	3	-2,2	-8	-14,4	-19	-20,4	-11,8
65	**80**	-2	-2,2	-6	-12,4	-22	-23,4	-9,8
66	**102**	2	-4,2	-8	-16,4	-25	-44,4	-32,8
67	**66**	-1	4,8	7	17,6	11	4,6	4,2
68	**74**	1	2,8	-2	-14,4	-7	-7,4	-3,8
69	**123**	2	-2,2	-19	-30,4	-40	-50,4	-53,8
70	**68**	2	-11,2	-4	-12,4	-18	-8,4	2,2
71	**113**	-3	-16,2	-30	-31,4	-44	-56,4	-43,8
72	**83**	-2	-5,2	-3	0,6	-9	-13,4	-13,8
	Average	**0,2**	**-6,1**	**-10,9**	**-15,8**	**-20,7**	**-26,7**	**-19,8**
	Std. Dev.	**2,4**	**6,8**	**11,0**	**15,7**	**16,5**	**20,3**	**18,9**

4 CONCLUSIONS

A collaborative forecasting agent-based model to support the decentralized supply chain has been proposed. Thus, under the supply chain network supported by multiagent systems, the deviation was lower compared with the real demand than the traditional forecasting process when considering a collaborative forecasting demand. In addition, full collaboration among the nodes was not seen to be necessary, but at list of more than a half of them to collaborate is needed to generate real contribution from this collaborative forecasting process. In future research, the proposed model will be applied to a real supply chain network in the automobile supply chain sector, and will consider real demand data.

ACKNOWLEDGEMENTS

This research has been carried out in the framework of a project funded by the Spanish Ministry of Science and Education, entitled 'Simulation and evolutionary computation and fuzzy optimization models of transportation and production planning processes in a supply chain. Proposal of collaborative planning supported by multi-agent systems. Integration in a decision system. Applications" (EVOLUTION project, DPI2007-65501, http://www.cigip.upv.es/evolution).

REFERENCES

Aviv, Y. (2001). The Effect of Collaborative Forecasting on Supply Chain Performance. Management Science, 47(10): 1326–1343.

Filipe, J. (2003). Information Fields in Organization Modeling Using an EDA Multi-agent Architecture. Agent-Mediated Knowledge Management, 2926: 130-142.

Hernández, J.E, Mula, J., and Ferriols, F.J. (2008). A reference model for conceptual modelling of production planning processes. Production Planning & Control, 19(8): 725–734.

Liang, W. Y., and Huang, C. C. (2006). Agent-based demand forecast in multi-echelon supply chain. Decision Support Systems, 42: 390–407.

Poler, R, Hernandez, J. E, Mula, J., and Lario, F.C. (2008). Collaborative forecasting in networked manufacturing enterprises. Journal of Manufacturing Technology Management, 19(4): 514-528.

Rodriguez, R., Poler, R., Mula, J., and Ortiz, A. (2008). Collaborative forecasting management: fostering creativity within the meta value chain context. Supply Chain Management: An International Journal, 13(5): 366–374.