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Automated Negotiation System in the SCM with Trade-Off Algorithm

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Abstract **–**Today, supply chain management is regarded as an essential strategic factor which has a great deal of influence on earning competitiveness in the abruptly changing global business environment. Multi-agent technology becomes the best candidate for problem solver under these circumstances. In SCM, improving the efficiency of the overall supply chain is of key interest. Because of market globalization and the advancement of e-commerce the importance of supply chain network is increasing. A supply chain can produce products for multiple markets. Also, an individual company is likely to have only limited visibility of the supply chain structure, which makes it difficult to make future demand forecast, because the pattern of demand propagation through the supply chain depends on the capabilities and strategies of companies along the path from the markets to the company. There will be the conflict among the pursuit of the profit of all members of the SCM. In order to maximize the total profit of the SCM, negotiation among all members is necessary. The aim of this paper is to develop a heuristic computational model of the trade-off strategy and show that it can be lead to an increased the profit of all members of the SCM. The trade-off algorithm is proposed in order to provide the total maximum profits and the minimum difference in profits of both attendances in negotiations. And multi-agent based automated negotiation system could be transformed into linear programming with negotiation information. The ideas behind the suggested model are trade-off algorithm with an agent and we consider multiple decision variables that are color, price, mileage, and delivery date. Multi-agent based automated negotiation system is compared with negotiation system with trade-off mechanism. Utility function is used as a performance measure in order to compare offer set that purchasing agent receipted. In this research, only purchasing agent and supplier agent is considered. And multi-agent based automated negotiation system is able to find the best negotiation strategy that makes all members of the SCM satisfied in a simple SCM.

Keywords: Supply Chain Management, Negotiation, Multi-Agent, trade-off mechanism

1. Introduction

Effective supply chain management (SCM) involves activities to solve the conflicts between demand and supply of resources and services. SCM need a high level of intelligence for planning, scheduling, and change adaptation. And they should be able to support distributed collaboration among companies. Collaborations in supply chains cannot be governed by a single company in a one-directional way, but needs to be coordinated by autonomous participation of companies. For these reasons, agent technology is regarded as one of the best candidates for supply chain management

Negotiations in supply chains may relate to a wide range of details in transaction processes, including the product specification, cost and pricing policy, trade terms and so on. During the negotiation process, the reaction of the negotiation opponents and the dynamics of the market circumstances should be captured. In the supply chain system of manufacturing enterprise based on multi-agent, every agent respectively on behalf of all the different department, organization or enterprises, and driven by interests, and cooperate\e with each other, to complete the process from the purchase of raw materials, processed products, manufacturing, and distribution to final customer or market. We view negotiation as a bargaining process by which a joint decision is made by two parties. Automated negotiation is a key form of interaction in systems composed of multiple autonomous agents. In this work it is researched that the conflicting preferences over complex multi-dimensional decision problems involved in the bi-lateral resource allocation negotiation of services. In negotiations, one producer and one consumer have to bargain and come to a mutually acceptable agreement over terms and conditions under which the producer will execute some activity for the consumer. This paper presented a heuristic negotiation algorithm that is a linear for performing trade-offs in automatic negotiations. The goal of this paper is to demonstrate the value of incorporating one heuristic, the similarity heuristic, in the trade-off decision mechanism for a given set of conditions.

2. Negotiation System

In the supply chain of manufacturing enterprise based on agent, decision making can be supported by any number of heuristics that assist it in searching for potential deals. In the decision model presented in this paper the reasoning process of an agent at each sequence of the negotiation is characterized as meta deliberation over the execution of either a concessionary or a trade-off mechanism or both. The mechanism models iterative concession over the score of a contract based on facts such as the amount of resources consumed in the negotiation, the time remaining until the due date, and the behavior of the negotiation opponent. This paper only discusses the negotiation between purchasing agent and supplier agent. Figure 1 shows the multi-agent based automated negotiation systems.

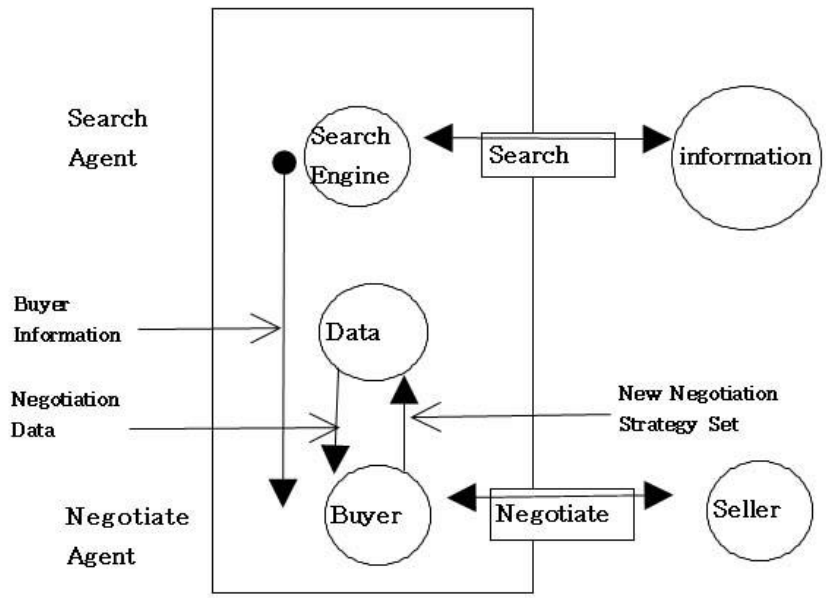

Fig. 1. Multi-agent based automated negotiation systems.

Let i represent the negotiation agent and j be the decision variables under negotiation. Negotiations can range over quantitative or qualitative decision variables. Decision variables are defined over a real domain or defined over a partially ordered set. Each agent has a scoring function V that gives the score it assigns to a value of decision variable j in the range of its acceptable values. Scores are kept in the interval [0, 1]. Weight that gives the importance of decision variable j for agent j means the relative importance that agent assigns to each decision variable under negotiation. Both parties have a deadline by when they must complete the negotiation.

In the trade-off negotiation mechanism problem is how to select a contract that is likely to increase the score of the opponent, given that the agent does not know its preferences. To make trade-offs, an agent in negotiation with another agent must be provided with a mechanism to select a set of contracts all of which have the same utility as opponent's previous offer X and to select from this set, a contract X' that agent believes is more preferable to opponent Than X.

3. Trade-Off Algorithm

Multi-dimensional decision problems present opportunities for increasing the social profit of the deal through trading off between decision variables. In this paper there is a concessionary strategic mechanism for assigning values to decision nodes. This mechanism fails to explore the space of potentially jointly better solution nodes because it cannot explore different possible value combinations for the local negotiation decision variable. For example, a contract in which the service consumer offers to pay a higher price for a service if it is delivered later. From the service provider's point of view, the former may be acceptable and the latter may not. The suggested model does not allow the agents to explore for such possibilities because it treats each decision variable independently and only allows agents to concede on decision variables. To increase the efficiency of deals, agents need the ability to make-offs between negotiation decision variables. The heuristic is based on the degree of similarity between two consecutive contracts. The agent can use fuzzy similarities to guess the prior probabilities of the other's decisions and then update these prior probabilities in the course of interactions using Bayes rule.

From the perspective of the fuzzy set literatures, a fuzzy similarity relation on a set D is a binary function Sim: D x D→[0,1]. The method of building similarity functions is to define criteria evaluation functions. Thus, given a criteria evaluation function, h: D→[0,1], a natural way to define a similarity function induced by h is to define, $\mathrm{Sim}_h = h(x) \leftrightarrow h(y)$,where ↔ is a fuzzy equivalence operator. For instance, for T(u,v)=max(0, u+v-1), h(x)↔h(y)=1-|h(x)-h(y)|, and for T=min, h(x)↔h(y)=1 if h(x)=h(y), and h(x)↔h(y)=min(h(x),h(y)) otherwise.

Given a domain of values, D_j , a similarity between two values $x_j, y_j \in D_j$ is defined as $Sim_j(x_j, y_j) = \sum_{1\le i\le m} \omega_i \cdot (h_i(x_j) \leftrightarrow h_i(y_j))$ where $\sum_{1\le i\le m} \omega_i = 1$, and h(x)↔h(y)=1-|h(x)-h(y)|. And the similarity between two contracts x and y over the set of decision variables J is defined as $\mathrm{Sim}(x, y) = \sum_{j\in J} \omega^a{}_j \cdot Sim_j(x_j, y_j)$ with $\sum_{j\in J} \omega^a{}_j = 1$. Given a scoring value θ, the iso-curve at level θ for agent a is defined as $iso_a(\theta) = [x|V^a(x) = \theta]$. The agent needs to select the contract that is most similar to agent b's last offer. A trade-off is defined as: Given an offer, x, from agent a to b, and a subsequent counter offer, y, from agent b to a, with $\theta = V^a(x)$, a trade-off for agent a with respect to y is defined as $trade - off_a(x, y) = \arg \max_{z\in iso_a(\theta)} \{Sim(z, y)\}$

The trade-off algorithm is defined over the class of linearly additive utility functions.

The trade-off algorithm is as follows

1. It starts at contract y
2. Moves towards the iso-curve associated with x, the agent's last offer.
3. Moves to iso-curve is performed sequentially in s steps.
4. generating n contracts that have a utility E greater than the contract selected in the last step, y^j
5. from the generated child contracts, select the one that maximizes the similarity with respect to the opponent's contract y

Fig. 2 shows the part of the algorithm responsible for generating a new trade-off contract.

4. Mathematical Model

Mathematical model for negotiation system can be used as an another approach. Linear programming is used with objective function that maximize the sum of buyer utility and seller utility. Constraints mean that the difference between two player's utility is under predetermined threshold. And decision variables are under the domains.

Objective function: Maximize Z=Buyer Utility + Seller Utility

Subject to

$|\text{Buyer Utility} - \text{Seller Utility}| \le \text{threshold}$

$\text{min. of range} \le x_j \le max. of\ range \quad for\ i = 1,2,..n$

After finding optimal solution, branch and bound enumeration is used for integer decision variable.

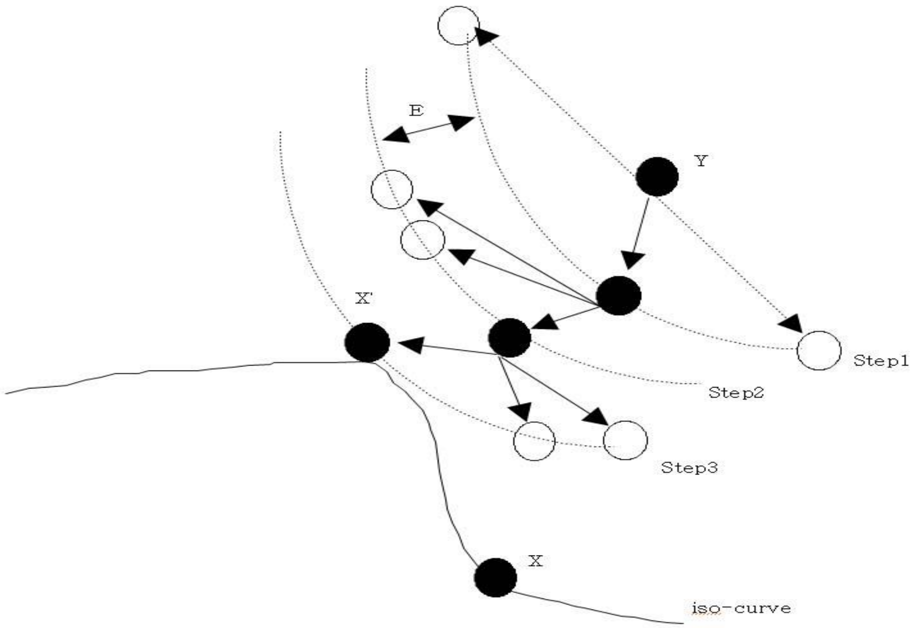

Fig. 2. Schema of the trade-off algorithm

5. Case Study

Consider the example of a car-dealer negotiating the purchase of a car. Assume agent a enters the garage and receives the initial proposal x=(green, \$27,000, 80,000km, 10 weeks) for a deal on buying a car of a given model (over decision variables=[color, price, mileage, delivery]). Agent a responds to this proposal with a counter proposal y=(yellow, \$21,000, 40,000km, 0 weeks). In order to use trade-off technique domains, weights, value functions and the similarity function for the car dealer should be specified.

$D^b{}_c = [yellow, violet, magenta, green, cyan, red]$
$D^b{}_p = [\$10{,}000,\ \ \$40{,}000]$
$D^b{}_m = [5{,}000km,\ \ 180{,}000km]$
$D^b{}_d = [0\ weeks,\ \ \ 16\ weeks]$

Value functions are as follows,
$V^b{}_c = [(yellow, 0.5), (violet, 0.2), (magenta, 0.3)\ , (green, 0.8), (cyan, 0.3), (red, 0.8)]$
$V^b{}_p = \frac{x_2 - 10{,}000}{40{,}000 - 10{,}000}$
$V^b{}_m = \frac{x_3 - 5{,}000}{180{,}000 - 5{,}000}$
$V^b{}_d = \frac{x_4}{16}$
And weights are $\omega_c = 0.1, \omega_w = 0.8, \omega_l = 0.06, \omega_v = 0.04$
Similarity functions are as follows,
For the similarity of color, three different criteria can be considered.
These are warmness, luminosity, and visibility.
Given these three criteria, color can be modeled in the following way.
$h_w = [(\text{yellow}, 0.9), (\text{violet}, 0.1), (\text{magenta}, 0.1), (\text{green}, 0.3), (\text{cyan}, 0.2), (\text{red}, 0.7)]$
$h_l = [(\text{yellow}, 0.9), (\text{violet}, 0.3), (\text{magenta}, 0.6), (\text{green}, 0.6), (\text{cyan}, 0.4), (\text{red}, 0.8)]$
$h_v = [(\text{yellow}, 1), (\text{violet}, 0.5), (\text{magenta}, 0.4), (\text{green}, 0.1), (\text{cyan}, 1), (\text{red}, 0.9)]$
Where $h_w, h_l, and\ h_v$ are the criteria functions.

And assume that the weights for the different criteria are $\omega_w = 0.7, \omega_l = 0.2, \omega_v = 0.1$.
Then the similarity relations are
$Sim_c(\text{yellow}, \text{red}) = 0.83$
$Sim_c(\text{yellow}, \text{violet}) = 0.27$
Similarity for price, mileage, and delivery are modelled as follows,

$$h_p(\text{x}) = \begin{cases} 1 - \frac{x_2}{40{,}000} & , \quad x \in [0,\ 40{,}000] \\ 0 & , \quad otherwise, \end{cases}$$

$$h_m(\text{x}) = \begin{cases} \frac{180{,}000 - x_3}{180{,}000 - 5{,}000} & , \quad x \in [5{,}000,\ 180{,}000] \\ 0 & , \quad otherwise \end{cases}$$

$$h_d(\text{x}) = \begin{cases} \frac{18 - x_4}{18} & , \quad x \in [0,\ 18] \\ 0 & , \quad otherwise \end{cases}$$

From the car dealer's point of view, contracts x and y have different values;
$V^b(\text{x}) = 0.5840$
The value of agent a offer is
$V^b(\text{y}) = .3553$
After one more step, three children contracts will be generated.
$X_1 = (\text{yellow},\ 29{,}055.38,\ 44{,}096.25,\ 5\ \text{weeks})$
$X_2 = (\text{red},\ 26568.\quad 99{,}017.78,\ 12\ \text{weeks})$
$X_3 = (\text{violet},\ 30{,}556.51,\ 258.47,\ 7\ \text{weeks})$
$V^b(X_1) = V^b(X_2) = V^b(X_3) = 0.5840$

Now, the trade-off algorithm selects the one with highest similarity with respect to the offer made by agent a, that is contract y, using the car dealer's decision variable weights
$\text{Sim}(\text{y}, X_1) = 0.8264$
$\text{Sim}(\text{y}, X_2) = 0.8257$
$\text{Sim}(\text{y}, X_3) = 0.7067$
Given these values, the algorithm would chose X_1 as the trade-off to customer a.
That is, $X' = (\text{yellow}, \$\ 29{,}055.38, 44{,}096.25\text{km}, 5\ \text{weeks})$

In order to use trade-off technique domains, weights, value functions and the similarity function for the customer should be specified as follows.
${D^a}_c = [yellow, violet, magenta, green, cyan, red]$
${D^a}_p = [\$5{,}000,\ \$50{,}000]$
${D^a}_m = [0km,\ 200{,}000km]$
${D^a}_d = [0\ weeks,\quad 20\ weeks]$
Value functions are as follows,
${V^a}_c = [(yellow, 0.5), (violet, 0.2), (magenta, 0.3)\ , (green, 0.8), (cyan, 0.3), (red, 0.8)]$
${V^a}_p = \frac{50{,}000 - x_2}{50{,}000 - 5{,}000}$
${V^a}_m = \frac{200{,}000 - x_3}{200{,}000}$
${V^a}_d = \frac{20 - x_4}{20}$
And weights are $\omega_c = 0.2, \omega_w = 0.7, \omega_l = 0.06, \omega_v = 0.04$
Similarity functions are as follows,
Assume that the similarity of color is the same as car dealer.
Similarity for price, mileage, and delivery is used as follows,

$$h_p(\text{x}) = \begin{cases} 1 - \frac{x_2}{50{,}000} & , \quad x \in [0,\ 50{,}000] \\ 0 & , \quad otherwise, \end{cases}$$

$$h_m(\mathrm{x}) = \begin{cases} \frac{200{,}000 - x_3}{200{,}000} & , \quad x \in [0,\ 200{,}000] \\ 0 & , \quad otherwise \end{cases}$$

$$h_d(\mathrm{x}) = \begin{cases} \frac{20 - x_4}{20} & , \quad x \in [0,\ 20] \\ 0 & , \quad otherwise \end{cases}$$

From the car buyer's point of view, contracts x and y have different values;

$V^a(\mathrm{x}')$ =0.5026

The value of agent a offer is

$V^a(y)$ =0.6391

After one more step, three children contracts will be generated.

$Y_1 = (\text{yellow},\ 21{,}000,\ 26{,}667.04,\ 2\ \text{weeks})$

$Y_2 = (\text{yellow},\ 20{,}742.86.\quad 26{,}667.04,\ 4\ \text{weeks})$

$Y_3 = (\text{green},\ 24{,}021.44,\ 50{,}000,\ 5\ \text{weeks})$

$V^a(Y_1) = V^a(Y_2) = V^a(Y_3) = 0.6391$

Now, the trade-off algorithm selects the one with highest similarity with respect to the offer made by agent b, that is contract x', using the car buyer's decision variable weights

$\mathrm{Sim}(\mathrm{x}', Y_1) = 0.8761$

$\mathrm{Sim}(\mathrm{x}', Y_2) = 0.9313$

$\mathrm{Sim}(\mathrm{x}', Y_3) = 0.9117$

Given these values, the algorithm would chose Y_2 as the trade-off to customer a.

That is, $Y' = (\text{yellow}, \$20{,}742.86, 26{,}667.04\text{km}, 4\ \text{weeks})$

These process will be continue until the difference of value function between two successive contracts of agent a and agent b is less than the predetermined threshold.

6. Conclusion

Supply chains can change over time and companies in supply chains can have only limited visibility of the supply chains. This paper suggested a multi-agent system that makes negotiation through suggested model. The ideas behind the suggested model are negotiation with trade-off mechanism and negotiation with considering a lot of factors. This paper presented a formal heuristic model with trade-off algorithm that has been the use of fuzzy techniques for the design of negotiation agent architecture. The entity in supply chain of manufacturing enterprise can be abstracted into the independent agent by the application of agent technology. The particular technique adopted was fuzzy similarity in order to cope with the inherent uncertainties in the negotiation process. And empirical evaluation demonstrated the algorithm's effectiveness in generating trade-offs in a range of negotiation contexts.

References

Ahn, H.J., & Park, S.J. (2003). Modelling Of A Multi-Agent System for Coordination of Supply Chains with Complexity and Uncertainty. *Lect. Notes. Comp. Sci.*, 2891, 13–24.

Faratin, P., Sierra, C., Jennings, N.R. (2002). Using Similarity Criteria to Make Issue Trade-Offs In Automated Negotiations. *Artificial Intelligence*, *142*, 205-237.

Radu, S., & Lungu, V. (2013). An Adaptive Multi-Agent Model for Automated Negotiation. *19th Internatioanl Conference on Control Systems and Computer Science*, 167-174.

He, M., & Jennings, N. R. (2004). Designing a Successful Trading Agent: A Fuzzy Set Approach. *IEEE Transactions on Fuzzy Systems*, *12*(3), 389–410.

Kim, H. S., & Cho, J. H. (2010). Supply Chain Formation Using Agent Negotiation. *Decision Support Systems*, *49*, 77-90.

Wang, G.H., Jiang, X., Yu, T., Gong, Y., & Wang, W (2006). Research on Supply Chain Negotiation under Networked Manufacturing Environment. *Proceeding of the Sixed International Conference on Intelligent Systems Design and Applications (ISDA'06).*

Fang, Y. X. (2008). A Life-cycle-oriented Agent-based Negotiation Framework for Supply Chain Management. *Proceedings of the 7th World Congress on Intelligent Control and Automation*, 25-27.

Changhui, Y. (2007). Multi-object Negotiation Mechanism in Supply Chain Management based on Multi-Agent. *The 33rd Annual Conference of the IEEE Industrial Electronics Society(IECON)*, 5-8.

Um, W.S., Lu, H., & Hall, T. J. K. (2010). A Study of Multi-Agent Based Supply Chain Modeling and Management. *iBusiness, 2*, 333-341.