Complex and Concurrent Negotiations in Supply Chain Management (Position Paper)

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Abstract: Complex negotiation activities are carried out among supply chain management (*SCM*) stakeholders (e.g., raw material suppliers, sub-contractors, manufacturers, distribution centers, and end customers) for resolving the differences in expected prices of raw materials, fulfilling a job order, sub-component fabrication, etc. This position paper proposes an agent-based testbed consisting of 1) customer agents acting on behalf of distribution centers, 2) manufacturer agents acting on behalf of manufacturers, and 3) supplier agents acting on behalf of raw material suppliers and sub-contractors that fabricate sub-components for a manufacturer. This position paper presents a complex negotiation mechanism for modeling the parallel negotiation activities in multiple interrelated markets where the outcomes of the concurrent negotiations between a manufacturer and multiple suppliers and sub-contractors will affect the manufacturer's negotiations with distribution centers. This is because paying higher costs for raw materials to suppliers and/or higher costs for sub-component fabrication to sub-contractors will incur higher costs in the manufacturer's products to distribution centers. The complex negotiation mechanism consists of: 1) a *relaxed-criteria negotiation protocol* and *adaptive negotiation* strategies for customer and manufacturer agents in a customer market and 2) *contracting and coordination algorithms for concurrent negotiations* between manufacturer and supplier agents in multiple supplier markets.

Keywords: agent, automated negotiation, procurement management, supply chain management.

I. Introduction

In a supply chain, companies (stakeholders) interact for producing and delivering products/services. Since very few companies can produce end products for end customers from raw materials solely on their own, they generally need the assistance of other organizations. For instance, a company that supplies the raw materials is often not the same company that sells end products to end customers. To provide end products to end customers, a network of stakeholders is involved in activities such as purchasing, transforming, and distribution [1]. Supply Chain Management (*SCM*) generally involves managing a chain of activities linking interconnected businesses (e.g., manufacturing and distribution processes from transforming raw materials to finished products for distribution to end customers). Negotiation activities are carried out among *SCM* stakeholders (e.g., raw material suppliers, sub-contractors, manufacturers, distribution centers, and end customers) for resolving the differences in expected prices of raw materials, fulfilling a job order, sub-component fabrication, etc. Furthermore, complex negotiation activities in interrelated markets can also potentially occur in *SCM*. For instance, in a manufacturing *SCM* network (which consists of a chain of processes linking multi-tier suppliers, sub-contractors, manufacturers, distribution centers, retailers, and end customers), a manufacturer may need to negotiate contracts with suppliers, sub-contractors, and distribution centers. To fabricate a product, a manufacturer needs to acquire raw materials from suppliers and sub-components from sub-contractors. Hence, the manufacturer may need to concurrently negotiate with suppliers of multiple types of raw materials and sub-contractors that fabricate different sub-components. Moreover, the manufacturer also needs to negotiate product prices with distribution centers for distributing finished products to end customers. This position paper proposes an agent-based approach for modeling the negotiation activities of stakeholders in an *SCM* network.

II. Complex Negotiation Mechanism

Agent-based Testbed

An agent-based testbed is used for modeling a portion of an *SCM* manufacturing network. It consists of 1) customer agents acting on behalf of distribution centers, 2) manufacturer agents acting on behalf of manufacturers, and 3) supplier agents acting on behalf of raw material suppliers and sub-contractors that fabricate sub-components for a manufacturer. In this agent-based testbed, distribution centers are customers of a manufacturer, and raw material suppliers and sub-contractors are suppliers.

Complex negotiations in SCM

The contribution of this position paper is proposing a complex negotiation mechanism for modeling the parallel negotiation activities in multiple interrelated markets where the outcomes in one market can potentially influence those in another market. In an *SCM* manufacturing network, the outcomes of the concurrent negotiations between a manufacturer and multiple suppliers and sub-contractors will affect the manufacturer's negotiations with distribution centers. This is because paying higher costs for raw

materials to suppliers and/or higher costs for sub-component fabrication to sub-contractors will incur higher costs in the manufacturer's products to distribution centers. Figure 1 shows a complex negotiation mechanism for facilitating two types of negotiation activities: 1) between customer agents and manufacturer agents and 2) between manufacturer agents and supplier agents. In an *SCM* network, a many-to-many negotiation model will be adopted for facilitating negotiations between customer agents and manufacturer agents because each manufacturer will generally distribute products to many distribution centers, and each distribution center will generally receive products from different manufacturers. Additionally, since each manufacturer needs to acquire different raw materials and sub-components from different suppliers and sub-contractors, respectively, a concurrent one-to-many negotiation mechanism will be adopted to facilitate concurrent negotiation activities between manufacturer agents and different groups of supplier agents.

Negotiation Protocols and Strategies

The complex negotiation mechanism shown in Figure 1 consists of: 1) a *relaxed-criteria negotiation protocol* and *adaptive negotiation strategies* for customer and manufacturer agents in a customer market and 2) *contracting and coordination algorithms for concurrent negotiations* between manufacturer and supplier agents in multiple supplier markets. In such a complex negotiation scenario, manufacturer agents have dynamic reserve prices and dynamic utility functions because their negotiation outcomes in a supplier market (e.g. paying a higher price for a raw material) can potentially influence the outcomes in a customer market (e.g. charging a higher price for a finished product).

Relaxed-criteria Protocol

By adopting a relaxed-criteria negotiation protocol [2], customer and manufacturer agents will be programmed to slightly relax their bargaining criteria under intense pressure with the hope of enhancing their chance of successfully reaching agreements. Two criteria that can influence a customer agent's decision in determining the amount of relaxing its bargaining terms are: 1) recent statistics in failing/succeeding in acquiring products, i.e., *failure to success ratio* and 2) *demand for finished products*. Two criteria that can influence a manufacturer agent's decision are: 1) recent *requests for finished products* from customers and 2) the costs for acquiring raw materials and sub-components for fabricating products. For example, from the perspective of a manufacturer agent, if there are fewer recent demands from customer agents for finished products, a manufacturer agent is *more* (respectively, *less*) likely to slightly relax its bargaining criteria since it is under *more* (respectively, *less*) pressure to distribute finished products. If a manufacturer agent needs to pay *higher* (respectively, lower) prices for acquiring raw materials and sub-components for fabricating a product, then it is *less* (respectively, *more*) likely to slightly relax its bargaining terms.

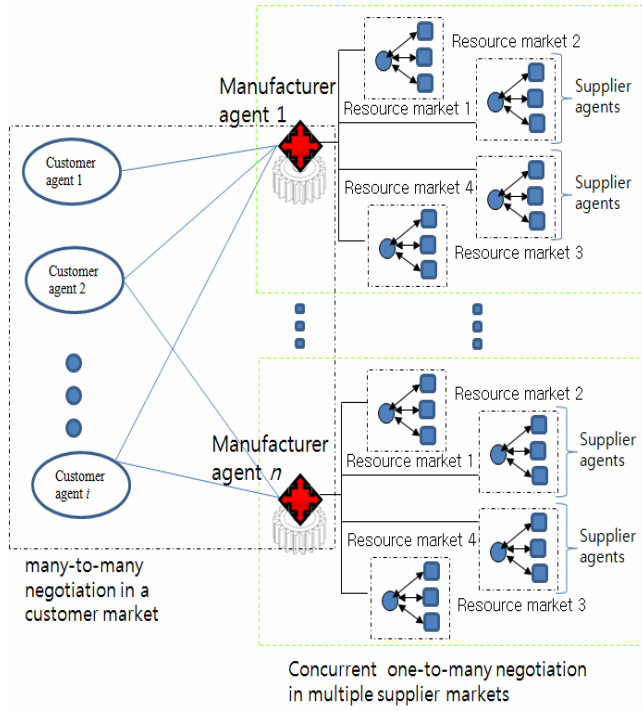

Figure 1. A Complex Negotiation Model for Multiple Interrelated Markets

Adaptive Negotiation Strategy

It is anticipated that customer and manufacturer agents will adopt an adaptive negotiation strategy to determine the appropriate amount of concession at each negotiation round using 1) a time-dependent concession making function and 2) a function for determining the bargaining position of the agent.

Time Function

Since customer agents are generally sensitive to deadlines in acquiring finished products, and manufacturer agents may also have deadlines in gathering raw materials and obtaining sub-components, it is intuitive to consider time when formulating the negotiation decision functions. Both a manufacturing agent's and a customer agent's time-dependent concession making strategies can be classified into: i) *conservative* (maintaining the initial price until an agent's deadline is almost reached), ii) *linear* (conceding linearly), and iii) *conciliatory* (conceding rapidly to the reserve price) [3].

Bargaining Position

One method to model market competition in a many-to-many negotiation is to consider an agent's bargaining position B_p. In a *favorable market* (respectively, *unfavorable*

market), a customer agent is in an *advantageous* (respectively, *disadvantageous*) B_p because there are *more* (respectively, *fewer*) manufacturer agents fabricating products and *fewer* (respectively, *more*) customer agents competing for products. In a *balanced market*, a customer agent is in a generally *neutral* B_p as the supply of products is not significantly more than the demand. One approach for estimating B_p at each negotiation round is to consider the concession patterns of an agent's opponents. If manufacturer agents are making relatively *larger* (respectively, *smaller*) concessions, then it is likely that a customer agent is in a relatively *favorable* (respectively, *unfavorable*) B_p. The B_p of a manufacturer agent can also be estimated in a similar way by considering the concession pattern of each customer agent.

Concurrent Negotiation

For modeling the concurrent negotiation activities between a manufacturer agent and supplier agents, it is anticipated that a concurrent negotiation mechanism adapted from [4] will be used. The concurrent negotiation mechanism in [4] consists of a *coordinator* that coordinates the parallel negotiation activities for the acquisition of *n* different types of resources (raw materials) in *n* different e-markets. In each resource market, a manufacturer agent negotiates simultaneously with multiple supplier agents to establish contracts for one type of resource. Furthermore, both manufacturer and supplier agents can be freed from a contract (i.e., an agent can decommit a contract) by paying penalty fees to their opponents. The negotiation activities of the manufacturer agent in each resource market is managed by a commitment manager that manages both commitments and decommitments of (intermediate) contracts with supplier agents. In the concurrent negotiation mechanism, two algorithms are needed: 1) an algorithm for establishing contracts and managing commitments and decommitments of contracts and 2) an algorithm for coordinating the concurrent negotiation activities.

Contracting Algorithm

The contracting algorithm [4] consists of the following steps: 1) computing the subjective probability that a supplier will renege on an intermediate contract, 2) determining the expected utility that a supplier's proposal can generate, 3) determining if a supplier's proposal is acceptable taking into account penalty payments (if any), and 4) requesting and confirming contracts. Additionally, the concession-making strategy used by a consumer to generate its (counter-) proposals can affect the results of the negotiation.

Coordination Algorithm

The coordination algorithm generally consists of the following steps: 1) predicting the change in expected payoff in each one-to-many negotiation and 2) deciding whether the consumer should proceed with or terminate the entire concurrent negotiation [4].

Previous Empirical Results

Even though the complex negotiation mechanism has not been implemented for modeling complex negotiation activities in an *SCM* network, experiments were carried out previously to compare the contracting and coordination algorithms in the concurrent negotiation mechanism in [4] with the works in [5] and [6], respectively. Previous empirical results in [4] show that 1) the coordination algorithm in [4] achieved higher utility, faster negotiation speed, and higher success rates than the coordination algorithm in [5] for different resource market types and 2) the contracting algorithm in [4] achieved higher final utility than the contracting algorithm in [6].

Discussion and Summary

This position paper explores the issues of 1) finding an appropriate mechanism for modeling complex negotiations in *SCM* and 2) devising the negotiation protocols and negotiation strategies for customer agents, manufacturer agents, and supplier agents in the proposed agent-based testbed for modeling a portion of an *SCM* network. From the perspective of automated negotiation [7], the novelty of this position paper is introducing the idea that negotiation activities in the context of *SCM* are not restricted to only one market but parallel negotiation activities can be carried out in multiple interrelated markets where negotiation outcomes in one market can potentially influence those in another market. To this end, this position paper will offer an entirely new branch of thinking in automated negotiation.

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Kwang Mong Sim received the Ph.D. and M.Sc. degrees from the University of Calgary, Calgary, AB, Canada, and the B.Sc. (honors) (summa cum laude) degree from the University of Ottawa, Ottawa, ON, Canada. He is currently the Director of the Multiagent Systems Laboratory, Department of Information and Communications, Gwangju Institute of Science and Technology, Gwangju, Korea. He is a member of the Editorial/Advisory Board of numerous international journals. Professor Sim is an Associate Editor for the IEEE TRANSACTIONS ON SYSTEMS, MAN AND CYBERNETICS—PART C. He is also the Guest Editor of five journal special issues in agent-based Grid computing and automated negotiation, including the special issue on Grid resource management in the IEEE SYSTEMS JOURNAL. He was a Referee for several national research grant councils, including the National Science Foundation, and was a Keynote Speaker, a Program Vice-Chair, and a Panel Speaker in many conferences.