Journal of Information Processing Vol.20 No.3 614–621 (July 2012)

[DOI: 10.2197/ipsjjip.20.614]

Regular Paper

A Middle-Agent Framework Focused on the Role of Distributors

Hiroki Nakagawa[1] Akihiko Nagai[1,a)] Takayuki Ito[1,b)]

Received: September 15, 2011, Accepted: February 3, 2012

Abstract: In this paper, we propose to use a middle-agent framework to analyze a business model that is focused on distributors for win-win cooperation and collaboration by revealing the effect, the influence, and the requirement for consensus in cooperation and collaboration. Distributors can create good cooperation and collaboration by mediates between manufacturing and user companies. We give an example of the collaborative development of new products where a distributor mediating between maker and user companies. The Application Specific Standard Product (ASSP), which is an LSI for specific applications, is attracting attention. To develop an ASSP, both semiconductor and user companies must agree on the functions that the ASSP has and on how many ASSPs must be considered without disclosing secret information. In this paper, we model distributors in a collaborative development and implement a tool for an agent-based simulation, in which we imagine a market where a product is developed, sold, and bought. We investigate the role of middle agents, distributors and how they affect the market. In addition, we propose a framework for examining a new business model.

Keywords: middle-agent, MOT, mediator, ASSP, distributors

1. Introduction

In this paper, the authors propose a middle-agent-based framework to innovate a business model by promoting consensus building among many companies. This framework is a tool to analyze what is needed for consensus building as well as the effect and influence of collaborative development, which is unclear in the real world [1], [2]. New knowledge about consensus building can be acquired with this framework. Win-win relations for many companies can be realized by building consensus for multiple collaborative development among them [3], [4].

Cooperation and collaboration help many companies that collect resources such as technologies, knowledge, information, funds as well as creating new business and developing new products. Cooperation and collaboration have difficulty building a consensus, because most companies focused excessive emphasis on profit [5].

In the semiconductor industry, semiconductor companies are developed the Application Specific Standard Products (ASSPs) in collaboration with user companies. The collaborative development of products enables them to accurately get a market's need and create new technology, but building a consensus is difficult because collaborative development with a user company causes misunderstandings over the issues related to each business. With whom and how to build a consensus are an important problem in the collaborative development of products. Many researchers have discussed the methodology of consensus building. For example, Imada pointed out that consensus building based on autonomy and individuality is more important than social integration by agreement and analyzed its structure and function without considering management behavior [3]. This situation is the same in the contract theory. Nevertheless Ito discussed consensus building that concentrated on stakeholder's profits. Recently, the principled negotiations is beneficial for all stakeholders [8], [9]. Recently, in particular, it was also pointed out that principled negotiation is more important. Principled negotiation based on mutual gains approach and win-win negotiation [6], [7]. Furthermore, realization of principled negotiation is needed in order to create value. In the real world, most transactions among companies are one-to-one. Our paper focuses on consensus building in multiple collaborative development among many companies.

Actually, social structure is much complex than is thought. We consider consensus building in multiple collaborative development among many companies is important because the multiple consensus building can be more beneficial to both suppliers and users than that of one-to-one [1], [2]. In this paper, we utilize middle-agent-based framework to promote consensus building among many companies. The middle-agent model is proposed as one multi-agent system that consists of individual agents who are designed differently. Middle agents mainly match agents and assign tasks with requester's preferences and provider's capabilities [13]. When many companies design a business model in the real world, these companies cannot only make network but also create business model in collaborative development (Section 2).

In this research field, Kato focused on group decision making for a consensus building process, developed a support tool, and evaluated it, but didn't apply it to any concrete example [5].

1 Nagoya Institute of Technology, Nagoya, Aichi 466–8555, Japan
a) nagai.akihiko@nitech.ac.jp
b) ito.takayuki@nitech.ac.jp

Our approach has an important meaning at this point. This paper is organized as follows. The next section shows a concrete example in which a semiconductor distributor is playing the role of a mediator between semiconductor and user companies while developing an ASSP. The third section shows a model for negotiating collaborative development transactions. The fourth section shows an agent-based simulation result from that model. Finally, the last section provides a conclusion. We participated directly in this project and interviewed all related parties for the sake of objectivity. We asked many related parties the same questions to get exact information and collected data from websites and documents.

2. A high-performance Graphics Processing Unit

In this section, the authors explain the reason that pachinko manufacturers had needed a high-performance Graphics Processing Unit (GPU).

Pachinko Manufacturer's Approach to Developing GPUs

Since 1998, the Pachinko market grows popular of digital pachinko. Such new displays attracted many female customers to the games because they provided a sense of fun that previous pachinko parlors lacked. Pachinko manufacturers noticed that GPU improved the user experience. To solve this problem, leading pachinko manufacturer B developed a GPU in collaboration with a semiconductor company.

Pachinko Manufacturer B's Approach to GPU

First, Company B tackled the development of its own GPU. It approached a semiconductor distributor A who cooperated with a semiconductor company AXELL with image processing technology for computer graphics and achievement. A proposed that these three parties develop an ASSP together. Pachinko manufacturer B agreed and started development, which stopped soon. Again, distributor A proposed the productization of a GPU as an alternative to the development of ASSP to AXELL and pachinko manufacturer B. Pachinko manufacturer B abandoned its GPU but still wanted it, so they decided to participate in the productization of a GPU.

This LSI sold rapidly, and in 2009, its sales achieved 23% of all sales. It contributed to distributor A's achievement. In this paper, authors analyze distributor A's approach to the GPU.

2.1 Background of the Productization of a GPU

This subsection gives AXELL's background of the productization of a GPU.

Four Reasons Why the Productization of a GPU for Pachinko Was Decided

AXELL had many reasons for producing a GPU with their own image processing technology, which is their strength. First, the market scale of GPUs was expected to expand. Second, the prices of products were expected to increase if they included GPUs with high functionality and performance. Third, at that time, the market had no GPU for digital pachinko. Fourth, semiconductor companies had a negative attitude toward the pachinko market. For these reasons, AXELL, a small venture company, entered the pachinko market.

Table 1 Difference in minimum demand quantity and demand function.

Item	Company B	AXELL
demand quantity	Total 50,000/year	Total 300,000/year
demand function	wanted all functions all "required" 7 essential functions	want to classify functions realize "required" surely didn't realize "nice to have" didn't realize "specific" didn't know essential functions

Overview of AXELL and GPU

AXELL is a fabless venture company that was founded by Yuzuru Sasaki in 1996 to develop and sell semiconductors. Over 40 pachinko manufacturers have adopted AXELL's GPU. AG-3 is a standard GPU in the pachinko market. Currently AXELL is listed on the Tokyo Stock Exchange.

2.2 Function Problems and Quantity Problems

Minimum demand quantity and demand function are reasons why AXELL and Company B failed to build a consensus.

Why Minimum Demand Quantity does not Built a Consensus?

AXELL and B had to agree about minimum demand quantity and demand function. They failed to agree about the former. For AXELL, minimum demand quantity is the quantity that is replaced with these costs. For B, minimum demand quantity is the amount of GPUs that it could buy.

Since Company B didn't need to cover the development and production costs, AXELL had to solve this problem. B could buy not more than 50,000 pcs of GPUs. On the other hand, AXELL had to sell not less than 300,000 pcs of GPUs annually for FUJITSU to produce them. B's quantity was 50,000 pcs and AXELL's quantity was 300,000 pcs. Building a consensus was impossible because of the huge disparity between these two figures.

Why Demand Function does not Built a Consensus?

In the following section, the authors explain about the demand function. Functions can be classified into three categories by degree of demand. "Must have" is an essential function for GPUs. "Nice to have" is a recommended function but it isn't essential. "Specific" is a function that B particularly demanded. When producing the ASSP, there was a difference in the demand function between AXELL and Company B. B demanded too many functions. Generally in the productization of ASSPs, semiconductor companies give priority to "required" functions and avoid "convenient" or "specific" functions because of the high cost of development and productization. Company B demanded the following functions: ①3D, ②enhanced sprite efficiency, ③electrostatic protection, ④high data compression rate, ⑤D-RAM, ⑥ROM, and ⑦BGA package. B considered all of these functions "required" and demanded all of them. On the other hand, for AXELL, demand functions were those that each pachinko manufacturer recognizes as "required." AXELL didn't know which functions were "required." B wanted all functions; AXELL didn't know which function was demanded. They couldn't build a consensus. **Table 1** summarizes this situation.

The huge difference in their minimum demand quantity and demand function prevented them from building a consensus. If these companies could not develop ASSP, they do not get value.

That is, AXELL couldn't develop a GPU, and B couldn't get a high-performance GPU.

2.3 Building Consensus with Participation of a Semiconductor Distributor

The previous subsection showed that the differences in minimum demand quantity and demand function cannot built consensus. Next, the authors explain how a semiconductor distributor solved the problem and helped them build a consensus.

Semiconductor Distributor Mediates to Build a Consensus

In this example, the authors summarize how a semiconductor distributor filled the gap in the minimum demand quantity and demand function over which they failed to agree. With regard to minimum demand quantity, since Company A thought that it could sell the GPUs for pachinko to other companies, not only Company B, they contracted to buy 300,000 pcs LSIs with AXELL. This proposal filled the gap in the minimum demand quantity between the supplier and the consumer. For its demand function, Company A inspected 20 pachinko manufacturers, whose customers classified the functions demanded by Company B, and extracted the "required" functions. This proposal, which was based on their investigation about "required" functions, was important for AXELL who now recognized the functions that they should develop. This investigation led to an LSI that contained functions that Company B didn't want, but it agreed with A's proposal anyway. The investigation also showed that ⑤, ⑥, and ⑦ were "specific" and unnecessary functions because they caused a lack of internal memory if the contents become complex. They also cost more and needed high technology to mount the substrate. Due to mediation by A, the semiconductor distributor enabled AXELL and B to fill the gap in the minimum demand quantity and demand function and to build a consensus. A suggested that GPUs would produce competitive power for all pachinko manufacturers when A sold them. This new competitive power is making contents that have a sense of fun with a high-performance GPU. Many competitors could get the same high-performance GPU as B but it was worth developing an LSI with "required" functions because they could differentiate their product from others by the contents. The "required" functions secondarily simplified procurement for pachinko manufacturers and lowered market prices. Additionally greater sales increased the profits for AXELL.

3. Transaction Model in Product Development

In the previous section, we explained the semiconductor distributor's role in order to promote the co-development transaction. In this section, we focus on distributors as mediators and model a co-development transaction among suppliers and users based on the concrete example in Section 2. The model is utilized for middle agent simulation to examine multiple co-development among many companies. The authors propose a middle-agent framework for co-development based on the simulation result. This framework is a tool used to analyze what condition is needed for consensus building and how co-development affects companies, which is unclear in the real world. New knowledge about consensus building can be acquired with this framework. This framework can facilitate multiple co-development among many companies.

3.1 Product Market

In this paper, we suppose a market where suppliers s, users b, and mediators m develop and deals with product g. Suppliers, users, and mediators are denoted respectively by s, b, and m that are variables. Product g is dealt with by two parties, like the good in Ref. [10], but it is different from the good because the product doesn't exist initially. The product results from negotiation with a supplier and a user. The product's functions are decided in negotiation, so the same products aren't always distributed. In the semiconductor example, the product is a GPU and the function is a feature to realize computer graphics and to avoid block-noise. The number of defective LSIs increases if their size exceeds 5 mm^2. An IP core must be designed whose size minimizes defective LSIs. The LSI can't have all functions by factor of physical and economical limits. For example, if the LSI has three functions, it is denoted by a vector $g = (f_1, f_2, f_3)$ with function f. The LSI g consists of some functions that is denote by f_i. f_i has discrete value that means kinds of function. The LSI's functions are decided by the suppliers, users, and mediators.

3.2 Agent

Suppliers sell LSI to users. Suppliers have technologies to develop functions mounted on LSI. Each supplier can develop different functions. They have secret information about functions they can develop and each function's price. $p_s(g)$ are the values that indicate how much profit they add to LSI g. This value also means supplier's technical information, and represents what kind of LSI they can produce. The value is infinity if a LSI includes functions that the supplier cannot develop. Sale price of g is calculated by the sum of cost $c(f)$ and supplier's profit $p_s(f)$. The supplier's utility from LSI g is profit $u_b(g)$ made by selling the LSI and is calculated by Eq. (1):

$$u_s(g) = p_s(g). \tag{1}$$

Users purchase LSI from suppliers and have secret information about the functions that they demand and the valuation for function v_b. They also have limitations on maximum demand quantity. A user's utility from LSI g is different from the LSI's valuation and its price and is calculated by Eq. (2):

$$u_b(g) = v_b(g) - c(g) - p_s(g). \tag{2}$$

Mediators play the role of both suppliers and users. They buy products from suppliers and sell LSI to users. They mediate with suppliers and users to build consensuses. For this role, they collect secret information from suppliers and users. From suppliers, they gather technical information about functions to be developed and demand information from users about functions they need. In direct negotiation with suppliers and users, they don't disclose secret information. When a mediator mediates a negotiation, even if a supplier or a user tells the mediator its secret information, the information doesn't directly benefit the mediator. The information benefits the mediator only when the mediator has a successful negotiation. The mediator hence can collect secret information. Based on their technical and demand information, mediators help suppliers and users agree on a product's functions and quantity. For example, when arranging functions, mediators match user demands and supplier technology and consider the functions that will benefit them. When arranging quantity, they contract to sell LSI to many users if they fail to build a consensus because of the difference in supplier and user quantities. A mediator adds their profit as margin $\mathrm{mgn}_m(g)$ to the product's price and sells it. $\mathrm{mgn}_m(g)$ is the mediator's profit by margin of mediation. Mediator's add his profit as margin to the LSI's price and sell it. The authors suppose the margin depends on LSI that he proposes. The margin $\mathrm{mgn}_m(g)$ depends on LSI g. The margin is the mediator's utility:

$$u_m(g) = \mathrm{mgn}_m(g). \tag{3}$$

When dealing with q LSI, the utility value each agent gets from LSI g is $u(g)q$ that is LSI of utility u(g) and quantity q.

3.3 Transaction Process

Users propose their demand functions and negotiate with suppliers. Distributers mediate the negotiation with two parties to help build a consensus. The values of the LSIs' functions depend on user's needs for function, suppliers' profit that they add to functions, and costs of functions. The values for users is different from those for suppliers. We show three kinds of interaction between different agents to explain the actions of suppliers, users, and distributers in this market.

Suppliers and Users

The authors suppose a case in which a user directly negotiates with a supplier, arranges a LSI's functions, and handles it. Users have valuation v_b for each function. The higher the valuation of v_b is, the more the user wants the function. If v_b is zero, the user doesn't really want it. Users propose to suppliers products with the functions they want. In contrast, suppliers present the proposed product prices. This price is the sum of the developing cost of all functions in LSI c and supplier's profit p_s.

Users purchase the LSI by price, and the transaction succeeds with probability $P(q_s, q_b)$, which is denoted by the supplier's minimum demand quantity q_s and the user's maximum demand quantity q_b if the user's valuation exceeds the price presented by the suppliers. Compared with supplier's minimum demand quantity q_s, the bigger user's maximum demand quantity q_b is, the bigger probability $P(q_s, q_b)$ becomes. That is, building a consensus is difficult unless the user purchases as many LSI as demanded by the suppliers. We can consider various formula, but in this paper, $P(q_s, q_b)$ is a liner function of q_s/q_b. The negotiation breaks down if the valuation is smaller than the price.

Suppliers and Mediators

Consider the case in which suppliers interact with mediators. Suppliers disclose their secret information to mediators. Such secret information is their technology about which functions they can mount on the LSI and how many LSI they demand. With this information, a mediator promotes a negotiation that benefits the suppliers when mediators mediate between suppliers and users. Mediators are third parties who profit by effecting deals with suppliers and users. Suppliers tell mediators their secret information

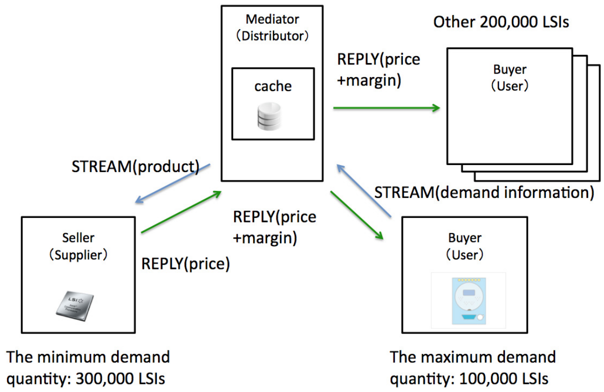

Fig. 1 Model of mediation.

because the mediators must produce a proposal on which both parties agree to get a profit.

Users and Mediators

Now we examine a case between users and mediators. Mediators act as suppliers for users. In practical terms, this means that users propose LSI to develop, not to suppliers, but to mediators. Mediators check the user's demand information and the supplier's technical information (each at function prices) to select a supplier as a trading partner. They consider which functions the LSI should have and propose them. The selected supplier presents its price to the mediator, based on the functions that the proposed LSI has. Mediators also add profit to the price and present this added price. The transaction succeeds with probability $p(q_s, q_b)$ if the user's valuation exceeds the new price. Additionally between users and mediators, the transaction depends on the supplier's and the user's quantities. Mediators can search for other users in reference to each user's demand information. Then they help build a consensus by forging deals over the same LSI with other users (**Fig. 1**).

3.4 Proposal for Function of LSI by Mediators

Mediators propose product functions to ask users about their demands and respond with supplier's technology. The strategy proposed by product mediators affects consensus building and each agent's utility. In the real world, mediators employ various strategies [1], [2]. In the semiconductor market, the semiconductor mediator proposed an LSI that has the functions wanted by many users, that is "required" and sells them to the semiconductor company after agreeing with the quantity and the functions. On the other hand, a mediator might propose a LSI that only responds to the user's demand. In our model, "required" and "specific" functions are decided by user's needs information that a distributor collected. "Required" functions are those that many users want. In contrast, "specific" functions are those that a few users want. There are other kinds of distributors. One distributor wants larger margin for insurance. The other distributor maximizes customer's profit for a good co-development. In our simulation, mediator agents used the following strategies:

A General demand

In this strategy, the mediator considers general demands based on demand information that it collected to find the combination of functions that maximize the sum of each user's valuation and proposes LSI g_a that satisfies Eq. (4):

$$g_a = \mathrm{argmax}_g \sum_b v_b(g). \tag{4}$$

B Customer demand

The mediator finds the combination of functions that maximize the customer's user's valuation and proposes LSI g_b that satisfies Eq. (5):

$$g_b = \mathrm{argmax}_g v_b(g). \tag{5}$$

C Myopia

In this strategy, the mediator finds a combination of functions that maximizes its own margin and proposes LSI g_c that satisfies Eq. (6):

$$g_c = \mathrm{argmax}_g \mathrm{mgn}_m(g). \tag{6}$$

D Reciprocity

Here, the mediator finds a combination of functions that maximizes the sum of the utilities of the supplier and the user for whom the distributer is mediating and proposes LSI g_d that satisfies Eq. (7):

$$\begin{aligned} g_b &= \mathrm{argmax}_g \{u_s(g) + u_b(g)\} \\ &= \mathrm{argmax}_g \left[v_b(g) - \{c(g) + p_s(g)\} - p_s(g)\right] \\ &= \mathrm{argmax}_g \left(v_b(g) - c(g)\right). \end{aligned} \tag{7}$$

Many researchers discuss about interaction between providers and requesters with game theory [11], [12]. In general, game theory has the following two indicators. First, game theory has an evaluation value representing the benefit. Second, game theory supposes that there are agents to make a profit. Actually, the our simulation is to optimize the evaluation value. Although, in this paper, users and suppliers do not fully understand their evaluation value. Mediators collect the complete information. With the information, it is possible to benefit stakeholders. Even if mediators have the complete information, they can not reuse the information, except matching stakeholders. Because of this, mediators can collect the information.

4. Simulation

4.1 Setting

The authors simulated a model in which suppliers, users, and mediators develop and trade with products g, research the effect on mediators, and consider the result. The simulation tool was developed in Java. In the simulation, we randomly paired the number of agents * 100 times. The pair consists of two different kinds of agents. For example, there is no pair of a supplier and another supplier. We ran 2,000 simulations and examined the average. The fixed parameters are 100 suppliers, 100 users, 20 functions, the maximum number of functions the product has, the number of functions each supplier can develop, and the number of functions users can demand.

The results are representative of the several hundred simulations tested, although values might vary between configurations of parameters. The differences between configurations of parameters were insignificant.

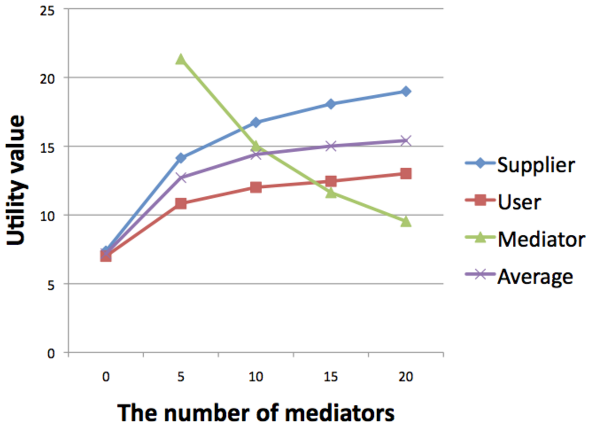

Fig. 2 Each agent utility.

Mediators use the general demand strategy and search for a supplier who can develop the product cheaper than anything on the market and mediate a transaction. In this simulation, the other agent parameters include supplier's and user's secret information and the mediator's margin.

We run simulation in the case where $P(q_s, q_b) = q_s/q_b$ simply.

4.2 Simulation Results

Effectiveness of Mediator

Figure 2 indicates the utility obtained by each agent from the product transaction by the number of mediators. The horizontal axis represents the number of mediators and the vertical axis represents the utility values. Suppliers, users, and mediators got higher utility values when mediators were involved. As the number of mediators increased, the utility value of the suppliers and users increases, although the mediator's utility value decreased as the number of mediators increased. The average agent utility values increased because the increasing rate of the supplier's and the user's utility values exceeded the decreasing rate of the mediator's utility value.

Mediators increase the total profit, although the mediator's utility value decreased because of the increasing number of distributors which obviously reflects the competition among distributors. Users can only make a deal with a supplier who has the technology to meet their needs, and suppliers are in the same situation. Trading partners are hampered to some extent if suppliers and users make a trade. In contrast, mediators can get a profit whoever they mediate if they build a consensus. Suppliers and users don't intend to develop another product and make a deal once they have satisfied the quantity condition. Therefore, the utility value average of the mediators drops because mediators get less profit as the other mediators get more.

Figure 3 shows the number of consensuses built by the number of mediators. The number increased when mediators are involved. Existing of many mediators made to build consensus.

The number of consensuses decreases when a supplier and a user negotiate directly without mediation as the number of mediators increases. Mediators collect information from suppliers and users. Mediators next mediate by matching a supplier with the technology to meet a user's need with the user. A supplier and user can pair off without mediation but the effect on mediating

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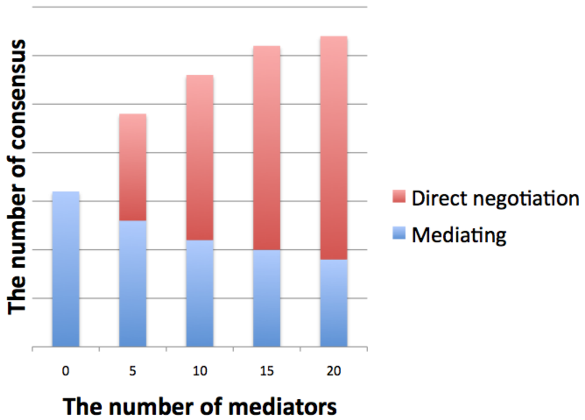

Fig. 3 Number of consensuses.

Table 2 General demand for products.

Case of negotiation	General demand
direct negotiation	3.92
mediation by mediator	4.09

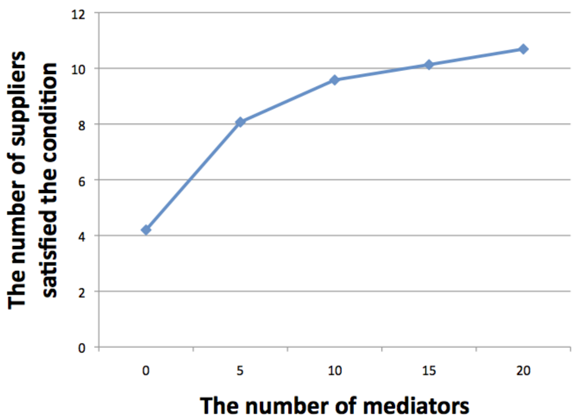

Fig. 4 Suppliers who satisfied the demand quantity.

takes precedence over direct negotiation and builds a consensus.

Examining Function

Table 2 indicates the general demand for functions developed in products by each case of negotiation. The general demand is calculated by the sum of all user valuations for the functions. When mediator mediate between user and supplier, demand is higher than when a user directly negotiates with a supplier. Products, which have more general demand, probably have more "required" functions that can be bought by many users.

Examining Quantity

Figure 4 shows the number of suppliers who dealt with as many products as the minimum demand quantity, which is the quantity to produce. The horizontal axis represents the number of mediators, and the vertical axis represents the number of suppliers who satisfied the condition. This number increased with the number of mediators increased. This result clearly suggests that broadening the market by mediators is effective.

Examining Mediator Strategies

One important role of mediators is proposing functions for products, based on the information collected from suppliers and users. Here, we simulated which proposal strategy benefits mediators or all agents and the characteristics of each strategy. The result without a mediator is shown for comparison. In the simulation setting, the number of mediators is fixed to 5, and the other parameters are the same as above. Each strategy is shown as follows: A: General demand, B: Customer demand, C: Myopia, and D: Reciprocity.

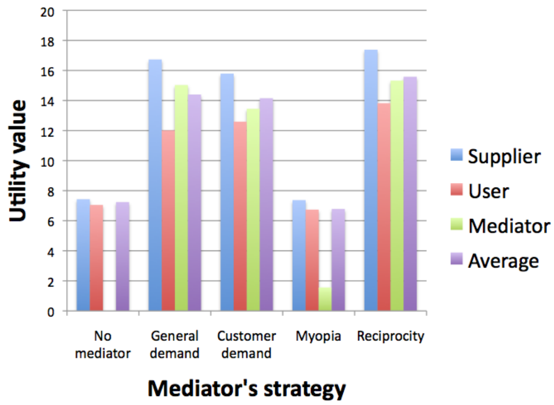

Fig. 5 Agent utility by mediator strategy.

First, we compare strategies A and B. The supplier's utility value is higher in A, and the user's utility value is higher in B. The mediator of strategy A emphasizes many user needs to broaden the market for the supplier. Therefore, the mediator probably isn't concerned about customer user needs, so the supplier's utility value is higher and the user's one is lower in strategy A. The mediator of strategy B only considers the customer user need, which is the product that contains "specific" functions so that the market becomes narrower. The supplier's utility value is lower and the user's is higher in strategy B.

The mediator of strategy C can't match suppliers and users because they behave selfishly. As a result, they can't help build a consensus and the utility value of all agents decreases. This situation is the same as having no mediator. In contrast, the mediator of strategy D emphasizes the profit of both the supplier and the user without considering their profit to simplify building a consensus; the mediator's utility value also increases. The result is indicated in **Fig. 5**.

Impact on Secret Information

In this simulation, we examine how the information collected by the mediator from supplier's technology and user's demand, affects negotiations. Originally, the information was collected from suppliers and users during the transaction. But in this simulation, we gave the mediators the initial information about all suppliers, all users, or both at the beginning to examine the impact of the quantity of information and on what kind of information.

Figure 6 indicates the utility value of each agent based on the initial information. We assumed that the utility value of each agent increases when mediators have information about both suppliers and users. In fact, the utility value is highest when mediators have only the supplier's information. User information seems to inhibit profit. Mediators exploit user information to sell products to many users. Figure 3 also shows that consensuses increase as mediators broaden the market. Therefore, the average profit per transaction decreases instead of broadening the market. By selling the same products to many users, mediators have no chance in the future to sell suitable products to users who already have them; the total utility value falls.

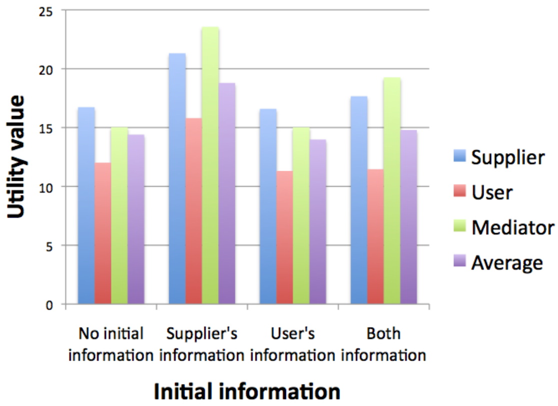

Fig. 6 Agent utility based on initial information.

5. Conclusion

This paper focused on a middle-agent solution for consensus building with cooperation and collaboration. The authors proposed a transaction model of product development and ran simulations with it based on a concrete example where a semiconductor mediator mediated the collaborative development of ASSP.

Mediators collect suppliers' and users' information. Mediating and extending the market with the information increase the number of consensuses. Proposing a product that both of agents want increases each agent's utility value, although, there is a condition that the average utility value per transaction decreases. The model mediated by mediators as middle agents is a usable framework for increases in the total profit of each agent and promotes to build consensus under conditions.

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Hiroki Nakagawa is a master course student of Department of Computer Science and Engineering, Graduate School of Engineering, Nagoya Institute of Technology. He received his B.E. degree from Nagoya Institute of Technology in engineering in 2010. His current research interests includes middle-agent, decision support system, and technology management. He is currently studying about visualization systems for business process.

Akihiko Nagai is a project professor at the Center for Green Computing of Nagoya Institute of Technology since April 2011. He graduated from School of Knowledge Science at the Japan Advanced Institute of Science and Technology (JAIST) as a master course student in 2006 and received a master degree in Knowledge Science. His main research interests include innovation ecosystems, consensus building on collaboration, and agent frameworks focused on semiconductor industries.

Journal of Information Processing Vol.20 No.3 614–621 (July 2012)

Takayuki Ito is an associate professor of Nagoya Institute of Technology, and a visiting scholar of MIT Sloan School of Management. He received his B.E., M.E., and Doctor of Engineering from the Nagoya Institute of Technology in 1995, 1997, and 2000, respectively. From 1999 to 2001, he was a research fellow of the Japan Society for the Promotion of Science (JSPS). From 2000 to 2001, he was a visiting researcher at USC/ISI (University of Southern California/Information Sciences Institute). From April 2001 to March 2003, he was an associate professor of Japan Advanced Institute of Science and Technology (JAIST). From 2005 to 2006, he was a visiting researcher at Division of Engineering and Applied Science, Harvard University and a visiting researcher at the Center for Coordination Science, MIT Sloan School of Management. From 2008 to 2010, he was a visiting researcher at the Center for Collective Intelligence, MIT Sloan School of Management. Since 2010, he has been a senior researcher of the Policy Alternatives Research Institute, the University of Tokyo. He is a board member of IFAAMAS, the PC-chair of PRIMA2009, and was a SPC/PC member in many top-level conferences (IJCAI, AAMAS, ECAI, AAAI, etc). He received the Young Scientists' Prize from Japanese Government, 2007, and several other awards. He is Principle Investigator of the Japan Cabinet Funding Program for Next Generation World-Leading Researchers (NEXT Program). In addition, he has several companies, which are handling web-based systems and enterprise distributed systems. His main research interests include multi-agent systems, intelligent agents, group decision support systems, agent-mediated electronic commerce, and software engineering on offshoring.