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A Multi-Agent System Model for Partner Selection Process in Virtual Enterprise

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Abstract

Virtual Enterprise (VE) is a collaboration model between multiple business partners in a value chain. VE information system deals with highly dynamic information from heterogeneous data sources. In order to manage and store dynamic VE information in the database, an ontology based VE model has been developed. To select winner enterprises in VE, a Multi Agent System (MAS) has been developed. Communication and data transition among agents and system entities are based on defined rules in VE ontology model. One of the most important contributions of agents in VE system is in partner selection step of VE formation phase. In this step several agents with different goals and strategies are collaborating and competing each other to win the negotiation procedure or maximize the profit for their assigned enterprise. Different strategies are developed for the agents depending on their appetite for winning the auction against maximizing the profit. Several simulations were run and the results are stored. These results are fed into a neural network in order to predict which enterprise will win the auction and what will be the profit margin. The motivation is to provide a forecasting agent for the customers about the outcomes of the auctions so that they can plan ahead and take the necessary action. Early results indicate such simulated multi-agent VE formations can be used in real systems.

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Keywords: Multi-agent systems; virtual enterprise; ontology; learning agents;

1.Introduction

A Virtual Enterprise (VE) is a temporary collaboration framework among multiple business partners in a value chain designed to reach business goals by sharing fundamental capabilities using information and communication technology (ICT) [1] [2]. The VE framework is particularly feasible and appropriate for SMEs located in industrial parks with other SMEs that have different vertical competencies. By cooperating within a VE framework, SMEs are able to combine their diverse competencies to develop new, higher quality products and reduce the effects of market turbulence [1], [3] and [4]. However, enhancing product quality and creating innovative, technologically advanced, high value added products requires more than forming a collaboration network among multiple manufacturing SMEs [5]. Thus, one of the main targets of this research is to include research and development startups, institutes or universities located in techno-parks or industrial parks to increase the ability of a VE consortium to produce innovative, high value added, high technology products. This approach would provide financial benefits while increasing market competitiveness by shifting SMEs production level.

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1.1. A trend is a direction VE Formation Phase and Agent Based Approaches

In this research in order to include design and development stage to VE lifecycle a new methodology for VE is proposed, and a new VE reference ICT system architecture has been developed (Fig.1) [6]. As this paper does not focus on VE lifecycle we are going through the multi agent approach in partner selection step of VE formation phase, in the following section of this article.

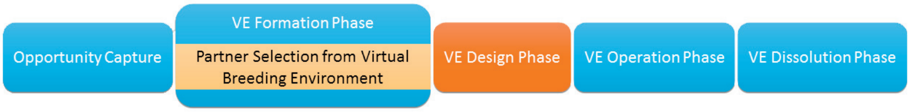

Figure 1Virtual Enterprise Lifecycle

In order to form up a new VE project, very first step is to select most appropriate partners from members' pool which is called Virtual Breeding Environment (VBE). The partner selection process is carried out based on four main criteria; price, Quality, Delivery Time and past performance. Two of these criteria are dynamic; proposed price and delivery time from competing enterprises and two of these criteria have static values which are obtained from database. A multistep elimination and selection processes using DEA, AHP, mathematical programming methods and fuzzy logics are included to select the most appropriate enterprises for the forthcoming VE project. But in order to feed the required values for dynamic criteria a multi agent based negotiation approach is proposed in this architecture.

Several researches regarding application of Multi agent systems in VE partner selection step have been concluded and different methods and approaches have been proposed by researchers in these studies. One of the studies in this era is done by Yang et al. They proposed a multi-agent based partner selection platform in order to choose best possible members, decompose project tasks and distribute them effectively among partners in the most appropriate way for VE projects. Based on this method agents negotiate between each other to win the auction [7]. A three layered multi-agent based architecture model containing business processes properties, registration and management for dynamic virtual enterprise has been proposed by Feng et al. [8]. Another multi-agent based approach for virtual entrepreneurship modeling and business processes is proposed by Gou et al. In this study two main group of resources and action agents cooperate to form up VE consortium [9].

One of the eminent studies in the formation phase of VE is PRODNET II project. In this massive project different tools and application to estimate resources, define enterprise profiles, configure VE structure, partner selection and evaluation, define management definitions and communication protocols and etc. have been developed [10].

Different Researchers attempt to develop fully automatic agent based platform for VE systems. Rocha, Daviddrajuh, Deng, Gou and others developed and defined broker and customer agents for different enterprises and designed a VE infrastructure. Unfortunately, due to lack of worldwide standards regarding agents messaging and collaboration these systems encountered tough problems and they barely fulfilled their orders [9] [11] [12]. In order to overcome to these problems interests over hybrid systems increased. In hybrid systems program and human agents are collaborating to satisfy system requirements. One of these hybrid designed systems was introduced in MASSYVE project. MASSYVE project is benefiting from an agent-based approach for partner selection and generating intra and inter organizational scheduling. For all the enterprises in virtual breeding environment (VBE) a common agent framework and standard is defined. In proposed system broker agents evaluate the business opportunities and the facilitator agents which are responsible for designing and planning of VE bargain with consortium agents in VBE to reach an agreement and select the best enterprise according to the defined criteria for cooperation in VE.

1.2. Applied auctions in VE systems

Based on order requirements and specifications, order is separated to different tasks. Each task has its own specifications and requirements and based on these needs, potential partners from VE pool put their bids to get involved in the forthcoming VE project and realize their intended task job. This part actually is the formation phase of VE and in order to select the most appropriate partners for each task job, a multi agent auction process is taking place. Here task manager agent is acting as buyer or customer agent and potential partners' agents are acting as seller which is called here enterprise agents.

There are several types of auctions which are studied and implemented in formation phase of VE. In literature mostly a company as a buyer has intention to form up a VE and suppliers as a whole try to bid and catch the opportunity to collaborate in VE platform. Here the competition is between the seller agents and each supplier tires to give the minimum price and satisfy customer (buyer) requirements and undertake the job therefore in such conditions reverse auctions or combinations of reverse auctions are mostly preferred and used in researches [13] [14] [15]. Combinational reverse auctions are mostly used to ease and realize the bidding on combination of items or tasks and combinatorial auctions are modeled mostly as set packing problems (SPP) [16] [17] [18] [19] [20].

2.Proposed auction model for VE Platform

In this research for partner selection stage of VE formation phase a hybrid multi agent model is developed. In this model several types of agents communicating to select the most appropriate enterprises for different project tasks. To select the winner enterprise for a project task, after a preliminary elimination processes, a set of agents are assigned to the qualified companies which are listed and potential partners from listed enterprises have to submit their bids, containing their proposed price, and delivery time and from other hand system obtains bidding companies static criteria; past performances and past quality performances values from VE database. In order to start the negotiation procedure, project agent which is responsible of all project task groups, deploys, task manager agents and consequently task manager agents assign enterprise agents to all bidding enterprises. Enterprise agents gather required information from company authorities like, bid opening price, maximum bidding price and company strategy during the negotiation process. Based on these information and companies' information in the system like enterprises past performance records, enterprise agent enters the negotiation procedure.

Here in negotiation procedure, enterprise agents are competing each other to give the most competitive price to the customer agent which here is the task manager agent. In the negotiation process all bids are sealed and enterprise agents are only informed about the best offer in the end of each iteration. According to enterprise agents information and incoming best bid of each iteration agent recalculates the iterations bid. In order to calculate the next bid from enterprise in VE partner selection negotiation process, the main equation is equation (1);

$$a_i = \left(\frac{b_{i-1}+f(\alpha)}{2}\right) - Epp.Cp.\left(\frac{b_{i-1}-f(\alpha)}{2}\right) \tag{1}$$

Here in this equation a_i is the next price in the bidding procedure (next iteration price of enterprise), and Epp is the enterprises' past performance, Cp symbolize how severe is the negotiation process for the company. $f(\alpha)$ is the price estimation formula for each company for the step.

In this formula Epp is obtained from system database and Cp is calculated from relation below;

$$Cp = \frac{b_{i-1}-a_{min}}{a_{i-1}-a_{min}} \tag{2}$$

In equation (2); a_{min} is the minimum price of the company in the negotiation process. a_{i-1} is the last bidding price of the company in the last iteration. $\alpha \; and \; \beta$ are fixed factors for enterprise strategy. Enterprise strategy determines the policy of enterprise and related agent in the negotiation process. Here as it is shown in figure 2 enterprise clarifies its strategy in negotiation which it desires to win the negotiation in anyway or it only considers to win the negotiation with a considered profit margin. According to the enterprise selection $\alpha \; and \; \beta$ factors are determined in a way that $\alpha + \beta = 10$.

In order to avoid radical bidding policies in VE negotiation process, to collapse negotiation in the very first steps, some preventions and stoppages are designed in the bidding procedure. In each step companies are allowed to bid in secure bidding range which is between a_{imin}, a_{imax}. a_{imin} is the minimum value that agents can bid for the next iteration likewise a_{imax} is the maximum value for bidding for agents. These values are calculated from the equations (3), (4);

$$a_{imin} = \frac{a_{min}+b_{i-1}}{2} \tag{3}$$

$$a_{imax} = \frac{3}{4}a_{min}(D_r + 2) + b_{i-1}\left(\frac{1-3D_r}{2}\right) \tag{4}$$

Figure 2 Enterprise strategy point

Also to find out the secure bidding range gap we have;

$$G = a_{imax} - a_{imin} \tag{5}$$

Based on these relations we are going to drive the formula for next bidding price of the enterprise. Here we have a third degree equation for price estimation.

$$f(\alpha) = a\alpha^3 + b\alpha^2 + c\alpha + d \tag{6}$$

Considering our boundary conditions we obtain;

$$f(\alpha) = a\alpha^3 - 15a\alpha^2 + 75a\alpha + a_{imin} \tag{7}$$

Now we give the minimum and maximum values for our function to find a value.
If we assume $a_{imax} - a_{imin} = \gamma$ whereγ, actually is the gap between a_{imax} and a_{imin} then we have;

$$a = \frac{a_{imax} - a_{imin}}{250} = \frac{\gamma}{250} = 0.004\,\gamma \tag{8}$$

Here the gap is showing the secure bidding band where enterprises next bids are allowed to be placed. Picture 3 shows the secure band (gap).

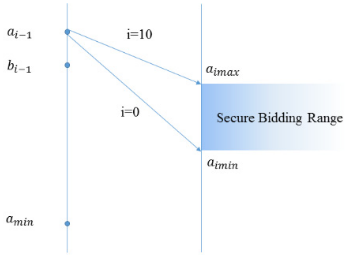

Figure 3 Secure bidding range

Therefore final form of the new pricing formula will be like equation (9);

$$f(\alpha) = 0.004\gamma\alpha^3 - 0.06\gamma\alpha^2 + 0.3\gamma\alpha + a_{imin} \tag{9}$$

For each iteration we assume that for a_{imin} we have;

$$a_{imin} = \frac{a_{min} + b_{i-1}}{2} \tag{10}$$

This assumption is based on the idea of preventing enterprises to bid aggressively and avoid them to put their minimum price in preliminary stages of negotiation. Therefore the minimum band of secure bidding range is designed to be the average of minimum price of enterprise and best price of the last iteration. From other hand enterprises have desires to hold prices as high as possible, then they will try to keep the price close to last iteration best price. However, there should be a range to allow prices drop below the best price. In this case a D_r constant is introduced to the system which is equal to a constant percentage of best price, and this would be the minimum price decline ration that an enterprise should offer below the last iterations best price. For a_{imax} we have;

$$a_{imax} = a_{min} + D_r(b_{i-1} - a_{imin}) \quad (11)$$

Therefore the γ formula becomes;

$$\gamma = \frac{1-D_r}{2}(a_{min} - b_{i-1}) \quad (12)$$

By replacing these amounts in the main formula we obtain;

$$f(\alpha) = \left\{\frac{1-D_r}{2}(a_{min} - b_{i-1})\right\}\{0.004\alpha^3 - 0.06\alpha^2 + 0.3\alpha\} + \frac{a_{min}+b_{i-1}}{2} \quad (13)$$

Finally in order to include E_{pp} and C_p factors to the final enterprise bid and calculate the bidding price of enterprise we have the following function;

$$a_i = \left(\frac{b_{i-1}+f(\alpha)}{2}\right) - Epp.Cp.\left(\frac{b_{i-1}-f(\alpha)}{2}\right) \quad (14)$$

$$a_i = b_{i-1}.\left\{\frac{1-Epp.Cp}{2}\right\} + f(\alpha).\left\{\frac{1+Epp.Cp}{2}\right\} \quad (15)$$

Combining equations (13) and (14) we obtain;

$$a_i = b_{i-1}.\left\{\frac{1-Epp.Cp}{2}\right\} + \left\{\left\{\frac{1-D_r}{2}(a_{min} - b_{i-1})\right\}\{0.004\alpha^3 - 0.06\alpha^2 + 0.3\alpha\} + \frac{a_{min}+b_{i-1}}{2}\right\}.\left\{\frac{1+Epp.Cp}{2}\right\} \quad (16)$$

3.VE Agents Auction Simulation Results

The developed agent strategies were tested using a simulation environment. The software development for agent interaction environment was implemented using JADE framework.

84 random auction simulations were created and the behavior of each agent within those auctions were stored. Some of the simulated results are tabulated in Table (1a). The results indicate that the agents that have more tendency in winning strategy has a better chance of winning the auction compared to the agents that prefer higher profit as expected.

Table 1 (a) Sample Results for Auction Agent Simulation

Auction No	*Winning Agent Strategy (Win or Profit) 0 = Win, to 10 = Max Profit)*	*Average Agent Strategy*	*Percent Profit of Winning Agent*
1	3	4.2	19.6
2	6	5.4	3.1
3	4	4	8
4	8	3.2	10.1
5	0	5.6	1.7
6	5	4	9

(b) Neural network performance for auction result estimation

Performance metric	*Training Data*	*Cross Validation Data*	*Test Data*
Correlation coefficient R	0.99952	0.99435	0.99609
Absolute Percent Error	2.27	9.77	6.52
MSE	24.19	311.91	185.80

4.Neural network model for Auction Result Prediction

The simulation results were used as data set for a neural network prediction model for estimating the auction result and the winner. Multilayer Perceptron was the chosen NN model in this study. The inputs used in the neural network model are strategies of agents, customer prices and the relative bids for each agent in the first 5 iterations. The output of the neural network is the forecasted auction results, i.e. which agent will win the auction and the auction closing price.

100 different auction simulations were used for the neural network data set. 70 of them were used as training data, 15 was used for cross validation and the remaining 15 was used as the test data. Table (1b) summarizes the performance of the neural network model.

5.Conclusions

The VE auction environment was generated and tested using an ontology based data model and JADE framework. In addition a neural network model was implemented for predicting the auction outcome. The results indicate that such a model can be used in a multi-agent model in a virtual factory environment where resources are shared and profit is maximized.

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