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Study of Partner Selection Based on GAS and Fussy Decision-Making

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Abstract

In this paper, based on GAS (Genetic Algorithms) and Fussy Decision-Making a partner selection algorithm by phases in manufacturing Extended Enterprise is presented. Based on the economy a mathematic model is built, and GAS is used to solve and reduce the range of partners. The decision is finally decided based on the result of GAS using the theory of fussy integrated decision-making and considering the other factors. In this method, the problem of partner selection of large scale extended enterprise can be resolved.
Keyword: GAS, Fussy Decision-Making, partner selection, model

I. Introduction

The enterprise that runs by the dispersive network manufacturing theory is called manufacturing extended enterprise. It is an organization that consists of a few institutes whose relations are collaboration and alliance. They can share knowledge and resources, and they can collaborate to produce a kind of production or service [1].

Because of the dynamic, collaborative and dispersive characters of manufacturing extended enterprise, how to select the best partner is the key of construct the extended enterprise. Though many methods had been brought forward by authors [2][3][4], there isn't a good method to solve the problem of partner selection of large scale extended enterprise. So a new method by phases based on the theory of GAS and fuzzy decision-making is bought forward to solve the problem.

II. Model of Partner Selection

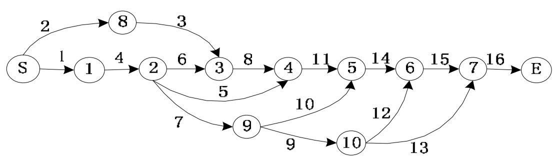

Fig. 1. Processing Task

In the extended enterprise, the owner of alliance catches the challenge of market and gets the order of production. It is designed and the exploitation of the virtual production is completed. If the owner enterprise hasn't the ability to produce it independently, the partners must be sought to build extended enterprise by network.

When the owner of alliance seeks partners, the task is divided into many sub-tasks. Then these sub-tasks are bid by network. Suppose the task is divided into *N* sub-tasks and there are relations between these sub-tasks. Such as figure 1, a task can be divided into 16 sub-tasks. In the figure, the end is supposed to be the end sub-task in order to convenience to judge which is the last sub-task. So the finish time of the end sub-task is the complete time of total task and it is denoted by the symbol of c_n. If the sub-task *K* can only start after the sub-task *i* is finished, these two sub-tasks are called correlative task. The symbol S_k denotes the start time of sub-task *K* and the symbol C_j denotes the finish time of sub-task *i*, so there is the equation: $S_k = C_j$.

The symbol $e(t)\{e(t) \geq 0, t = 1,2,\cdots D\}$ denotes the financing which is paid to the owner of alliance by the owner of the order (It is paid by stages as the developing of the program), and the symbol of *D* denotes the forecast finish time of the order. If the program is delayed, the owner of alliance must be paid for the penalty and the efficient of penalty is β

To the sub-task *i, i=1, 2, …n*, there is mi attended partner and the bidder of partner *j* to sub-task *i* is b_{ij} and the promise finishing time is q_{ij}. In order to simple this problem, we suppose that the owner of alliance paid $\alpha \times b_{ij}$ ($0 \leq \alpha \leq 1$) for the partners at the beginning of sub-task *i* and the rest is paid at the end.

The finance that the owner of alliance gets from the order's owner mustn't meet the need of sub-tasks, so the problem of lacking the finance will be appearance. Then, the owner of the alliance need loan from bank. So we suppose the interest rate is $\gamma(\gamma > 0)$.

From the point of benefit, the main of partners' selection is to gain the best benefit through the processing of the whole order. That is to say that the alliance of optimizing collaborative partners is to make the expensive minimum. So, the problem can be described as the following model.

$$\begin{cases} \min Z(x) = \sum_{i=1}^{n} b_{ix_i} + \gamma \sum_{t=1}^{c_n(x)} \left[\alpha \sum_{s_i(x)\leq t} b_{ix_i} + (1-\alpha) \sum_{c_{i(x)}\leq t} b_{ix_i} - \sum_{r=1}^{t} e(r) \right]^+ + \beta [c_n(x) - D]^+ \\ s.t.: \begin{cases} s_{ix_i} + q_{ix_i} = c_i(x) & i = 1,2,\cdots n \\ c_{ix_i} \leq s_{kx_i} & (i,k) are\ collective\ task \end{cases} \end{cases} \quad (1)$$

In the expressions (1): x_i is the selection partner to the sub-task *i*, and $c_n(x)$ is the finish date of alliance x, and *D* is the finish date of that is needed by the owner of order, and $[x]^+$ is $\max\{0, x\}$, and $Z(x)$ is total cost.

Because the function of this model isn't a continuous differentiable function and the range of the feasible solution is too wide, the traditional mathematic method can't get the effective resolution. Then we introduce the method of GAS to resolve this model.

III. Resolve the Problem by the Method of GAS

The basic thinking that we introduce GAS to get the result is[5]: defining the fitness function and the grade of membership; randomly sampling a group of individual as the initializing population, then selection and crossover and mutation to produce the new population; cycling the genetic operation till the evolution generation extends the max number. The concrete coding and operation is the following.

III.I. ***Coding principle and fitness function***

Let $x = [x_1, x_2, \cdots, x_n]$, in this formal x_i is an integer between 1 and m_i. So the symbol of *x* denotes a scheme of selection partners and it also denotes a chromosome in the GAS. For example, [3, 2, 5, 7, 2, 1] can be used to denote a kind of scheme of alliance that is consist of six partners. It represents the no.3 bidder to do the no.1 sub-task, the no.2 to do the no.2 sub-task and the no.5 bidder to do the no.3 sub-task and then on.

Because the fitness function is positive and the goal of function is to get the maximum currently, the model function (1) must be transformed as following:

$$fitness_l = Z_{\max} - Z(X_l) + \varepsilon \qquad l = 1,2,\cdots NP \qquad (2)$$

In the expression (2), *NP* is the population, $Z_{\max} = \max\{Z(x_l), l = 1, 2, \cdots, NP\}$ is the maximum from the computation of every generation, ε is an appropriate positive number

III.II. ***Selection***

The method of Roulette Wheel is the basic and common selection method, and it is also called MoteCarlo selection. In this method, the probability of selection every individual is in the proportion of the fitness:

Supposing the population is *NP*, and $fitness_l$ represents the fitness of individual l， and the probability of selection individual *l* is:

$$p_l = fitness_l \Big/ \sum_{l=1}^{NP} fitness_l \qquad (3)$$

Obviously, the probability p_l represents how much the proportion of the fitness of individual l that takes up in the sum of every individual. The fitness is bigger, the selection probability is higher.

III.III. ***Crossover***

The operation of crossover is an important character that is different from the other evolvement algorithms, and it is the main method to produce new individual. The method of two point crossover is often used in the GAS. The method is to set two crossover points randomly in a pair of individual and then exchange the gene between two points in order to produce new individual.

III.IV. ***Mutation***

The locus is randomly enacted in all individuals, and the value of gene in these louses mutates in the mutation probability Pm. When the mutation is operating, the value of all genes must be legal and it must be in the range of selection at the same time.

IV. Decision on the Theory of Fussy Decision-making [6]

A group of resolutions that are approximate to optimization can be gotten by the method of GAS, but the optimization isn't always the final selection scheme because there are other factors must be considered besides cost and benefit. For example: quality, credit standing, service, traffic, and so on. Then a method of grading is provided to select the partners. At the first stage, a set of feasible resolutions can be found by GAS to reduce the searching range. At the other stage, the most satisfying resolution can be found on the theory of fuzzy decision-making. By this way, we can analysis and make decision from several aspects to reduce count and improve rationality of decision-making.

IV.I. ***Confirm the Factor Set and Judging Set***

In the extended enterprise, production and service are provided by several enterprises and every enterprise only does one part of the whole program. On the theory of fuzzy integrated decision-making, there is a model of two levels to be adopted. So, the factors sets are: $U = \{U_1, \cdots, U_i, \cdots, U_n\}$, $U_i = \{u_1^{(i)}, \cdots, u_j^{(i)}, \cdots, u_{n_i}^{(i)}\}$. In the above set, n is the number of sub-task, and u_j is the single judging factor, and n_i is the number of judging factors to the no. i sub-task.

The symbol $V = \{v_1, v_2, \cdots, v_m\}$ denotes m judging sets. Because of the different status and functions of kinds of factors, the weight and judgment of every factor is also different. The integrated judge is a sub-set as $\tilde{B} = (b_1, b_2, \cdots b_m) \in \vartheta(V)$ because the judgment isn't absolutely affirmation and negation. In this sub-set, the symbol $b_j\,(j=1,2,\cdots,m)$ denotes the status of the no. j judge v_j in the integrated judge (it is the grade of membership of v_j to the fuzzy set $\tilde{B}$: $\tilde{B}(v_j)=b_j$). The integrated judge $\tilde{B}$ depends on the weight of every factor, and it is a fuzzy sub-set of U as $A=(a_1,a_2,\cdots,a_n)\in\vartheta(U)$ and $\sum_{i=1}^{n}a_i=1$ (the symbol a_i denotes the weight of the factor i). So, an integrated judging set $\tilde{B}$ can be gotten once the weight set A was given.

IV.II. ***Expert Judgment***

An expert group is built to judge the participant enterprises. A fuzzy judging set can be gotten by the way of expert's judging by the judging factors, rules through network.

IV.III. ***Integrated judge***

Firstly, the factors of second level cluster $U_i=\{u_1^{(i)},u_2^{(i)},\cdots,u_{n_i}^{i}\}$ can be judged, and it is to say that a fuzzy mapping is built:

$$\begin{aligned}&\tilde{f}_i\text{:}\;\; U_i\to\vartheta(V),\\&u_1^{(i)}\mapsto\tilde{f}_i(u_1^{(i)})=(r_{11}^{(i)},r_{12}^{(i)},\cdots,r_{1m}^{(i)}),\\&u_2^{(i)}\mapsto\tilde{f}_i(u_2^{(i)})=(r_{21}^{(i)},r_{22}^{(i)},\cdots,r_{2m}^{(i)}),\\&\cdots\\&u_{n_i}^{(i)}\mapsto\tilde{f}_i(u_{n_i}^{(i)})=(r_{n_i1}^{(i)},r_{n_i2}^{(i)},\cdots,r_{n_im}^{(i)})\end{aligned}\tag{4}$$

A judging matrix of single factor is gotten as $R_i=\left(r_{kl}^{(i)}\right)_{n_i\times m}$. Let the weight of $U_i=\{u_1^{(i)},u_2^{(i)},\cdots,u_{n_i}^{(i)}\}$ is $A=(a_1,a_2,\cdots,a_n)$, then the total judging matrix is $R=\left[\tilde{B}_1\quad\tilde{B}_2\quad\cdots\quad\tilde{B}_n\right]^T$. To compute in the operator of M , the integrated judge is gotten:

$$\underset{1\times k}{A}\circ\underset{k\times m}{R}=\underset{1\times m}{\tilde{B}}\in\vartheta(V)\tag{5}$$

IV.IV. ***Partner selection***

In this way, several fuzzy judging clusters are gotten after the selection schemes were judged by expert group. A score can be gotten by computing every scheme. Let the judging degree matrix is S , then the score can be gotten by formula (6). The highest score ($\max(score_i)$) is the selected scheme by ordering these scores.

$$score_i=\tilde{B}\bullet S^T\tag{6}$$

V. A simple example

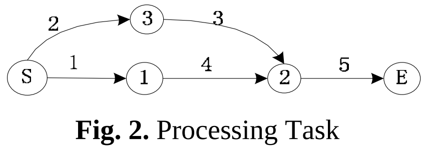

Fig. 2. Processing Task

Table 1. Payment

Time (week)	1	4	7	10	13	16	19	22	25	28	31
Money (10000)	8	8	8	8	10	10	10	10	10	10	8

An enterprise needs to bid for five sub-tasks (as figure 2) to built extended enterprise. The order owner will pay 1000,000 YUAN for these five sub-tasks and the terminate date is after 33 weeks. The payment shows as table 1 (the payment is paid by phases to the owner of alliance). The bidders show as table 2.

Table 2. Bidders for Sub-tasks

Sub-task	bidder	Bid (10000 YUAN)	Time (week)
Sub-task 1	A1	19	7
	A2	18.5	9
	A3	18	10
	A4	17	12
Sub-task 2	B1	18	8
	B2	16.5	9
	B3	14	10
	B4	12	12
Sub-task 3	C1	23	10
	C2	20	12
	C3	19	13
Sub-task 4	D1	19.5	9
	D2	18	11
	D3	17	12
Sub-task 5	E1	21	10
	E2	20	11
	E3	19	13

It is supposed that the owner of extended enterprise pays 60% money at the time of the sub-task is begging and pays the rest money at the time of sub-task is finish. If the program extends the order date, the factor of penalty is 20000 YUAN every week. Furthermore, the interest rate is 0.02 every day.

V.I. ***Get resolutions by GAS***

The GAS is programmed by the programming Language of Visual Fortran. The initial population is 20, and probability of crossover is 0.7, and probability of mutation is 0.005, and the generation of evolution is 100. Two optimized results can be gotten:

$X_1 = [4, 4, 2, 3, 1]$ $\quad Z(X_1) = 89.084$;

$X_1 = [4, 3, 3, 2, 1]$ $\quad Z(X_2) = 89.139$.

(1) Fuzzy decision-making

In the method of GAS, two schemes of partner selection are as following: A4, B4, C2, D3, E1 and A4, B3, C3, D2, E1. The first one is better than the second, but it mustn't be the final resolution. So we must make decision to select which one. Because A4 and E1 are both in two schemes, we only decide to select which one between the schemes B4, C2, D3 and B3, C3, D2.

(2) Confirm Integrated Factor Set and Judging Set

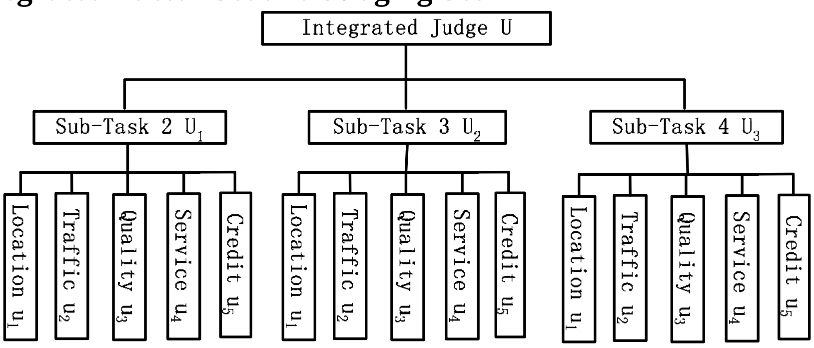

Fig. 3. Integrated Factor Cluster

Harmonious work and different function of every sub-task have been thought over. Firstly, the cluster of factors that influence the partner selection comes from the importance of every sub-task. Then the factors of location, traffic, quality, service and credit standing are thought over. In order to simple the problem, we suppose that the factors of every sub-task are same. Then, integrated factor cluster can be built as the figure 3 denotes.

(3) Confirm judging cluster

Judging cluster $V=\{v_1, \ v_2, \ v_3, \ v_4, \ v_5\}$ denotes the degree of satisfaction. In this cluster, v_1 is very satisfying, and v_2 is satisfying, and v_3 is almost satisfying, and v_4 is almost dissatisfying, and v_5 is dissatisfying.

(4) Expert judge

The jury of consisted of experts is to judge every bidder according to judging factors and rules. There are 8 experts to judge the first scheme and the second one. The judging result can be gotten as the table 3 shows.

In this table, the weight is $A=(a_1, a_2, a_3)$, $A_i=(a_1^{(i)}, a_2^{(i)}, \cdots, a_{n_i}^{(i)})$. The weights can be gotten in experience. Now we can suppose the weights of two levels are: $A=(0.3, 0.4, 0.3)$, $A_1=A_2=A_3=(0.2, 0.15, 0.3, 0.2, 0.15)$.

Table 3. Expert Judge to x_1 and x_2

system	weight	detail	weight	Judging result									
				v_1		v_2		v_3		v_4		v_5	
				x1	**x2**	**x1**	**x2**	**x1**	**x2**	**x1**	**x2**	**x1**	**x2**
Sub-task 2 U_1	a_1	**Location** u_1	$a_1^{(1)}$	4	4	3	4	1	0	0	0	0	0
		Traffic u_2	$a_2^{(1)}$	1	4	5	3	2	1	0	0	0	0
		Quality u_3	$a_3^{(1)}$	1	3	4	3	2	1	1	0	0	1
		Service u_4	$a_4^{(1)}$	2	4	3	3	3	0	0	1	0	0
		Credit u_5	$a_5^{(1)}$	2	4	4	2	2	1	0	1	0	0
Sub-task 3 U_2	a_2	**Location** u_1	$a_1^{(2)}$	5	2	2	4	1	1	0	1	0	0
		Traffic u_2	$a_2^{(2)}$	2	5	2	2	4	1	0	0	0	0
		Quality u_3	$a_3^{(2)}$	3	4	3	2	2	1	0	1	0	0
		Service u_4	$a_4^{(2)}$	3	5	3	2	2	1	0	0	0	0
		Credit u_5	$a_5^{(2)}$	1	3	4	2	2	2	1	1	0	0
Sub-task 4 U_4	a_3	**Location** u_1	$a_1^{(3)}$	3	4	4	2	1	0	0	1	0	1
		Traffic u_2	$a_2^{(3)}$	4	5	3	1	1	1	0	0	0	1
		Quality u_3	$a_3^{(3)}$	2	4	3	3	2	0	1	1	0	0
		Service u_4	$a_4^{(3)}$	3	4	4	2	1	2	0	0	0	0
		Credit u_5	$a_5^{(3)}$	4	5	4	2	0	1	0	0	0	0

(5) Integrated Judging

Firstly compute the first scheme (the parameters as the table 3 shows).

1) The factors of second level are judged.

$\tilde{f}$: $U_1 \to \vartheta(V)$,

$u_1 \mapsto (4/8 \quad 3/8 \quad 1/8 \quad 0 \quad 0) = (0.5 \quad 0.375 \quad 0.125 \quad 0 \quad 0)$,

$u_2 \mapsto (1/8 \quad 5/8 \quad 2/8 \quad 0 \quad 0) = (0.125 \quad 0.625 \quad 0.25 \quad 0 \quad 0)$,

$u_3 \mapsto (1/8 \quad 4/8 \quad 2/8 \quad 1/8 \quad 0) = (0.125 \quad 0.5 \quad 0.25 \quad 0.125 \quad 0)$,

$u_4 \mapsto (2/8 \quad 3/8 \quad 3/8 \quad 0 \quad 0) = (0.25 \quad 0.375 \quad 0.375 \quad 0 \quad 0)$,

$u_5 \mapsto (2/8 \quad 4/8 \quad 2/8 \quad 0 \quad 0) = (0.25 \quad 0.5 \quad 0.25 \quad 0 \quad 0)$。

The matrix of single factors is $R_1 = (u_1 \quad u_2 \quad u_3 \quad u_4 \quad u_5)^T$ and the weight is A_1.Because every factors need to be balanced according to their weights, the operator $M(\bullet \quad , \quad +)$ is selected (It is also $b_j = \sum_i^n a_i \times r_{ij} \quad (j = 1,2,\cdots,m)$).

$$\tilde{B}_1 = A_1 \circ R_1 = (0.2 \quad 0.15 \quad 0.3 \quad 0.2 \quad 0.15) \circ \begin{pmatrix} 0.5 & 0.125 & 0.125 & 0.25 & 0.25 \\ 0.375 & 0.625 & 0.5 & 0.375 & 0.5 \\ 0.125 & 0.25 & 0.25 & 0.375 & 0.25 \\ 0 & 0 & 0.125 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

$$= (0.24375 \quad 0.46875 \quad 0.25 \quad 0.0375 \quad 0)$$

Compute as the above:

$$\tilde{B}_2 = A_2 \circ R_2 = (0.36875 \quad 0.35 \quad 0.2625 \quad 0.01875 \quad 0)$$

$$\tilde{B}_3 = A_3 \circ R_3 = (0.375 \quad 0.44375 \quad 0.14375 \quad 0.0375 \quad 0)$$

2) The factors of first level are judged.

$U = \{U_1, U_2, U_3\}$, weight $A = (0.3, 0.4, 0.3)$. The result is:

$$\tilde{B} = A \circ R = (0.333125 \quad 0.41375 \quad 0.223125 \quad 0.03 \quad 0)$$

The final integrated judge denotes that the total judge is as following: the very satisfying degree is 33.31%, and the satisfying degree is 41.38%, and the almost satisfying degree is 22.31%, and the almost dissatisfying degree is 3%.

To the second scheme X_2, the result can be gotten as this method:

$$\tilde{B} = (0.49 \quad 0.315 \quad 0.10625 \quad 0.064375 \quad 0.024375)$$。

(6) Partner Selection

The grade of judge can be given a certain score as following: the very satisfying degree is 1, and satisfying degree is 0.85, and the general degree is 0.75, and the general dissatisfying degree is 0.5, and the dissatisfying degree is 0.3. It can be denoted by matrix as $S = (1 \quad 0.85 \quad 0.75 \quad 0.5 \quad 0.3)$. So the scores of two schemes are as following:

$$score_1 = (0.333125 \quad 0.41375 \quad 0.223125 \quad 0.03 \quad 0) \bullet S^T = 0.867;$$

$$score_2 = (0.49 \quad 0.315 \quad 0.10625 \quad 0.064375 \quad 0.024375) \bullet S^T = 0.877.$$

The scores are arranged in order and the highest score is the selection. So the scheme of X_2 is the selection and the A4, B3, C3, D2 and E1 will be selected to build the extended enterprise.

VI. Conclusion

The extended enterprise is dynamic, collaborative and dispersive. The problem how to select the optimized partner is the key to build the extended enterprise. In this paper, a method of grading is introduced to solve this problem. GAS is used to reduce the range of resolutions based on the model of economy. Furthermore, fuzzy decision-making is introduced to make decision on the second phase and many factors that influence partner selection are considered. The method of grading partner selection is suit for the great program that lasts long and there are many bidders.

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