Optimization of Enterprise Information System based on Object-based Knowledge Mesh and Binary Tree with Maximum User Satisfaction

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Abstract—**This paper deals with an approach to the optimization of enterprise information system(EIS) based on the object-based knowledge mesh (OKM) and binary tree. Firstly, to explore the optimization of EIS by the user's function requirements, an OKM expression representation based on the user's satisfaction and binary tree is proposed. Secondly, based on the definitions of the fuzzy function-satisfaction degree relationships on the OKM functions, the optimization model is constructed. Thirdly, the OKM multiple set operation expression is optimized by the immune genetic algorithm and binary tree, with the steps of the OKM optimization presented in detail as well. Finally, the optimization of EIS is illustrated by an example to verify the proposed approaches.**

Index terms—**enterprise information system, optimization, user satisfaction degree, object-based knowledge mesh, binary tree**

I. INTRODUCTION

With the development of science and technology, especially in information technology, various information systems began to appear, and were used in various fields. Thus far, various information systems [1~2] in different enterprises have played increasingly important roles in the field of management and decision-making. Although these information systems offer different advantages, they are basically independent from each other and have different limitations. Along with the variety of types of enterprises come the differences of demands regarding the functions offered by the information system. To date, no information system exits containing all of the functions suitable for all kinds of enterprises. However, if all kinds of information systems are transformed into their corresponding knowledge the enterprise can be allowed to select the most appropriate combination of information systems or the best mode for operation. Therefore, a knowledge mesh (KM) was brought forward to formally represent complex knowledge such as advanced manufacturing modes, information systems. And to solve the information exploration in KM representation, OKM was brought forward[3~4]. Only the information systems are formally represented, they can be optimized through mathematical methods.

The reconfiguration technique provides an effective approach to the adaptation of the enterprises to outward conditions and their increasing competitive power. The self-reconfiguration methods based on KM and AM are studied in Yan and Xue[5]. Similarly, Only if an optimal OKM multiple set operation expression[6] is obtained can the new optimal OKM be inferred from the expression to realize the optimal self-reconfiguration. Thus, optimization of an OKM multiple set operation expression is the key to those of the reconfiguration, which is the main objective of this paper.

To optimize an enterprise information system, firstly, the optimization object must be obtained. In this paper, user's function-satisfaction degrees are taken as the measurement on the EIS properties, as can be referred in reference[7]. Because users' function-satisfaction degrees vary with the OKM multiple set operation expressions that determine the forms and structures of objective functions, the optimization problem of an OKM multiple set operation expression is no longer the general linear, nonlinear or dynamic programming one. But it can be solved by connotative enumerative searching methods like genetic algorithm. Meanwhile, immune genetic algorithm (IGA) is the one often used in practice. Compared with traditional GA, the memory function of IGA can accelerate search speed, shorten search time, and save cost. It can also overcome premature phenomenon to a great extent. At present, the research on IGA mainly includes the following topics: 1) the study of improvements on IGA. 2) the study of applications of IGA. In terms of the first area, Duan[8] promotes and inhibit antibodies by calculating individuals' affinity and concentration and Liu[9] take similarity and vector distance as selection probability. An example of the second area includes: Bouchachia [10] solves the problem of testing data generation. However, IGA still has some

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deficiencies, *e.g.*, convergence cannot meet the expected target. Niche algorithm has the advantage of fast convergence, and it has been combined with many other optimization algorithms, such as ant colony algorithm and particle swarm optimization algorithm. These synthetic algorithms have been successfully applied to many fields like job scheduling and robots. So the convergence of IGA can be improved by niche algorithm. This synthetic algorithm can solve many optimization problems with better convergence, but when applied to level problems, its corresponding chromosomes are not simple, especially when information systems are too huge, even the chromosomes can describe their structure but always with poor understanding, which can be solved by tree structure, however. Tree structure is one of the important organization forms, and any problem with hierarchical relation can be represented by a tree. As the specific tree structure, binary tree is a fundamental data structure in computer science and with wide application. Such as reference [11] uses binary tree for dissimilarity data. These studies have enriched the theories of optimization algorithms and laid a foundation for the application of the improved IGA in EIS optimization. But there is no reference to this problem at present. Therefore, an improved IGA based on binary tree is adopted for optimization of OKM multiple set operation expressions, and the feasible OKM multiple set operation expression with user's maximal fuzzy function-satisfaction degree is obtained. And then, reconfiguration can be conducted to realize the new optimized enterprise information systems.

II. OKM MUTIPLE SET OPERATION EXPRESSION BASED ON BINARY TREE

An enterprise information system can be represented by a mesh known as the KM and OKM. From the OKM representing of an EIS, an AM is abstracted and simplified from the information system, after that, the OKM is utilized to represent the function modules, and then the information transfer relationship mesh (ITRM) is utilized to represent the relationships between OKMs, finally, the information system is represented by the OKMs and ITRMs. If the EIS need to be evaluated, the evaluation can be conducted on its formal representation, that is OKM, which is more easily realized in operations.

Since users usually focus attention on the functions of an information system, it is necessary to build the function-satisfaction degree model of an OKM and define its operations according to the relevant knowledge of fuzzy math[12] and user satisfation evaluation method in reference [7], in which user's function satisfaction evaluation method on information system are given. Based on these definitions, the user's satisfaction of the OKM multiple set operation expression can be obtained, which is the optimization object of this paper.

Based on above representation method, binary tree is used to represent OKM multiple set operation expressions further in this paper, which can make it easier to optimize EIS properties and more intuitive understanding in EIS optimization. According to different traversal methods, different expression can be represented as different binary tree structures. If the OKM multiple set operation expressions is $a+((b+c)-e)+d$, where $+,-$ represent operators of OKM, the above expression can be represented by binary tree in inorder traversal as shown in Fig.1.

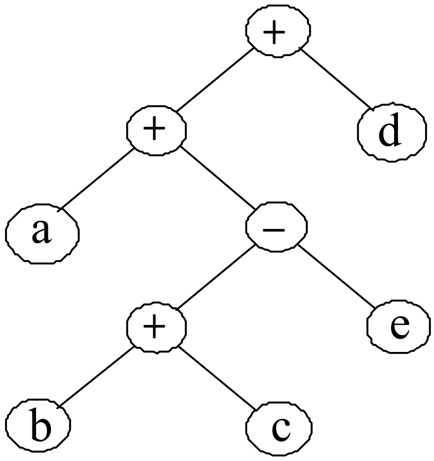


Fig.1 The binary tree of the structure

III. OPTIMIZATION MODEL OF EIS WITH MAXIMUM USER SATISFATION

A. Mapping Problem of the Solution Space

To solve the optimization problem of OKM multiple set operation expressions, relative evaluation criteria need to be established on the basis of the user's function-satisfaction degrees. The acquired function-satisfaction degree expressions are then mapped into their corresponding OKM multiple set operation expressions. The optimization process is shown in Fig.2.

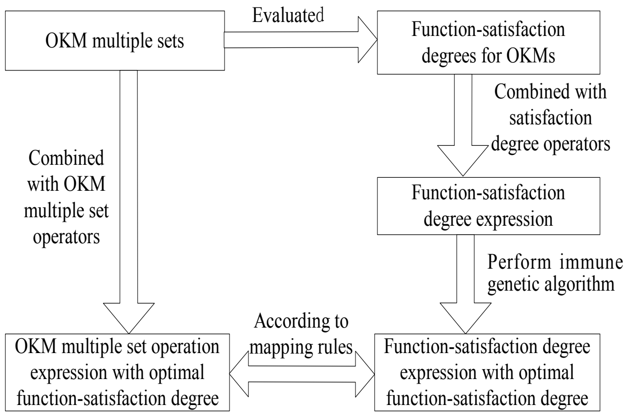


Fig.2 Optimization process of OKM multiple set operation expression.

Theorem 1: There is a one-to-one mapping between the OKM multiple set operation expression with brackets and N non-bracket operators and the function-satisfaction degree expression with N operators and the non-repetitive permutation of operator priorities.
Proof: Omitted.

B. Optimal Model of OKM Multiple Set Operation Expression

The objective of optimization is to obtain the optimized chromosome with the best fitness vector. Here, the fitness vector of the chromosome is the user's function-satisfaction degree vector. Thus, the objective function is

$$J = \max_{f_{m'n'}} \varepsilon\left(f_{\mathbf{m'n'}}(x), x_0 \right)$$

Where $f_{m'n'}$ is a fitness vector determined by the n'th chromosome in the m'th generation, which varies with the chromosomes. The computation structure of the objective function changes during the optimization process. The notation x is the n'th chromosome in the m'th generation. $\mathbf{x}_0$ is the ideal fitness vector and a row vector made up of 1 since the ideal satisfaction degree of each OKM-function is 1.

C. Immune Genetic Algorithm for OKM Multiple Set Operation Expression Optimization

Immune system is the defensive structure that body protects itself. It can detect and remove foreign bodies and factors, which fluctuate internal environment. After a serious of process, Pathogenic microorganism is cleared, in order to protect the body from attacks by viruses, bacteria and so on. The working mechanism of immune system enlightens scholars to have its ideas used in GA, i.e., Immune Genetic Algorithm. Compared with genetic algorithm based on immune principle and standard GA, IGA has the following advantages: (1) immune memory function; (2) maintaining antibody diversity function; (3) self-adjustment function. So IGA has its own unique advantages, while maintaining traditional GA's feature of global parallel search. Therefore, studies on IGA have important guiding significance.

When fitness in IGA is calculated, Niche algorithm can be used to select the best chromosome, and maintain the diversity of population. Improvements proposed in this paper are as follows:

Each fitness is adjusted according to (1).

$$sh(d) = \begin{cases} 1 - \dfrac{d}{\sigma_{share}} & d \le \sigma_{share} \\ 0 & d > \sigma_{share} \end{cases} \tag{1}$$

Where σ_{share} is the radius of Niche, and generally $\sigma_{share} = 0.1$; d is calculated according to (2).

$$d = \frac{d(opi,\ opj)}{m \times popsizel} \tag{2}$$

Where $d(opi, opj)$ is the Hamming distance between opi and opj, m is the number of genes in each chromosome, $popsize1$ is the number of chromosomes in each sub-group. Then the new method of calculating fitness is shown in (3).

$$\varepsilon\left(x_{opi}\right) = \frac{\varepsilon'\left(x_{opi}\right)}{\sum_{opj=1}^{N} sh\left(x_{opi},\ x_{opj}\right)} \tag{3}$$

To overcome Niche algorithm's deficiency of fast convergence, which leads to premature convergence, convergence function is introduced as follows.

$$f = \frac{\log(sum)}{\log(sum - 0.02)} \tag{4}$$

$$sum = \sum_{opj=1}^{N} sh\left(x_{opi},\ x_{opj}\right).$$

ALGORITHM 1: OKM multiple set operation expression optimization algorithm

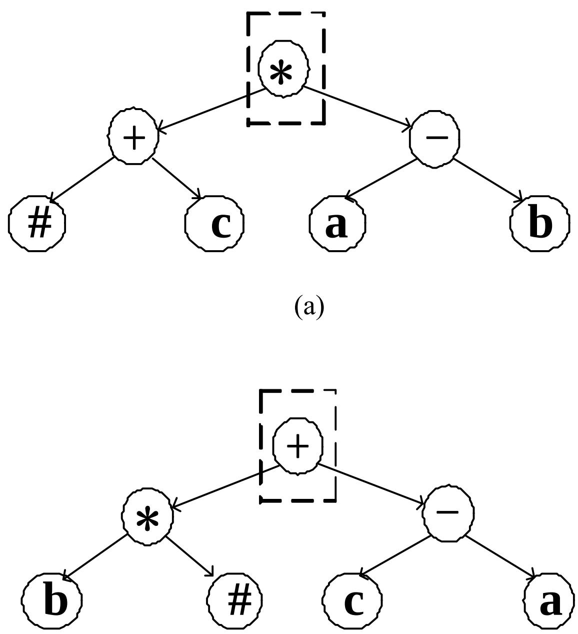
STEP 1 Initialize the parameters of the immune genetic algorithm, and population size is $popsize$.

STEP 2 Divide population into q_s sub-spaces uniformly, which have the following operations.

(1) Calculating and adjusting fitness according to above (1) and (2).

(2) Taking the first five optimal chromosomes as initial vaccine bank.

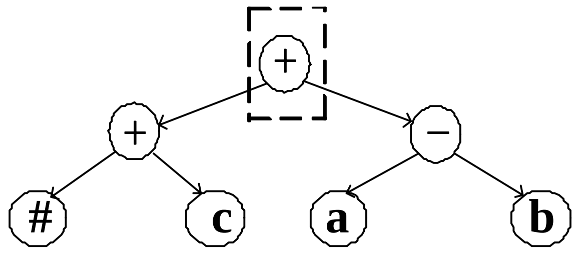
(3) Crossover operation. Single point is adopted, and cross point is selected between the intermediate nodes and the root node, then the two selected nodes exchanged each other, and then the two chromosomes with better fitness of all four will replace the initial two ones. The process is shown in Fig.3 and Fig.4.



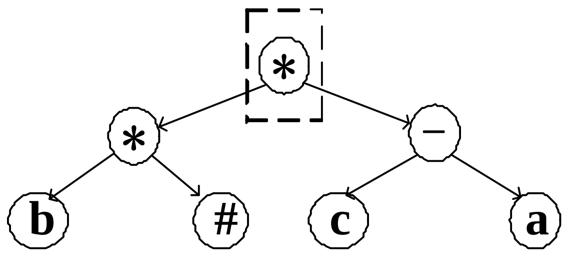
(a)

(b)

Fig.3 The selected trees before crossover operation



(a)



(b)

Fig.4 The selected trees after crossover operation

(4) Mutation operation. Mutation operation is applied to the intermediate nodes and the root node, as shown in Fig.5 and Fig.6.

(5) Judging evolution generation, if the maximum generation is divisible by present generation, then one chromosome is selected from pop_i, and will be vaccinated. Or the chromosomes are selected via a simulated roulette wheel selection.

(6) Adjusting vaccine bank. When the chromosomes' fitness values are lower than a given threshold ϕ, then the corresponding chromosomes will be preserved, or will be excluded from the bank.

(7) Updating sub-population and vaccine bank. Any chromosome's fitness is higher than a given value δ in pop_i, the corresponding chromosome is submitted to vaccine bank, and when the size of vaccine bank has been reached, the chromosome being submitted will replace the one with the lowest fitness in the bank.

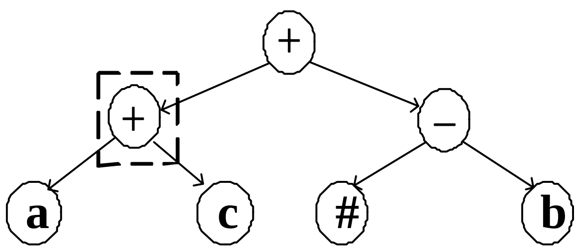


Fig.5 The tree before mutation

STEP 3 After each sub-population is calculated in sequence, judging the present generation, if it's greater than the maximum generation, then end the process, else $n = n + 1$, and go to step 2.

STEP 4 The best chromosome obtained above is transformed into the bracket-including OKM multiple set operation expression with the highest function-satisfaction degree.

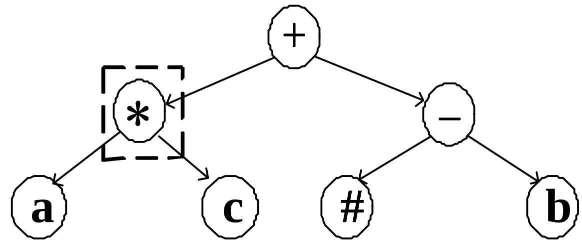


Fig.6 The tree after mutation

IV. OPTIMIZATION OF EIS WITH MAXIMUM SATISFACTION

Based on the OKM multiple set operation expression optimization algorithm, given below is the procedure of EIS optimization.

PROCEDURE 1: The steps of optimization of EIS with maximum user function satisfaction

STEP 1 The user's function requirements are layered by modules and sub-modules to facilitate the evaluation and management.

STEP 2 The existing information systems are represented as OKM and ITRMs according to the representation approach. And according to the user's requirement, other OKMs with complementary functions are selected from the base.

STEP 3 Intensive selection is to select the OKMs satisfying the user's function requirements from the OKMs selected preliminarily in STEP 2. The layer structure is adopted to evaluate the OKM functions, and the first two OKMs with the top evaluation (which is the simplified and overall evaluation, but not the final function-satisfaction degree to be optimized) of function i are selected for $i = 1, \cdots, n$ (All the OKMs selected intensively will be evaluated in STEP 4 and taken as operands of a OKM multiple set operation expression during the optimization process).

STEP 4 The OKMs selected through STEP 3 are evaluated and the function-satisfaction degree vectors for the OKMs are obtained by fuzzy evaluation methods in reference [7].

STEP 5 The OKM multiple set operation expression is optimized by ALGORITHM 1. The chromosome with the best fitness vector and the OKM multiple set operation expression with the highest function-satisfaction degree is then obtained.

STEP 6 A new OKM can be inferred from the step 5-obtained OKM multiple set operation expression with the highest function-satisfaction degree by the developed software platform so as to realize the reconfiguration of the OKM.

STEP 7 The new OKM and its ITRMs are mapped into the new information system, and the optimized information system is obtained.

V. EXAMPLES

Following the steps in optimization of an EIS, a simple example is given to show the optimization process. The user requirements are firstly transformed into layer structure according to step 1 of Procedure 1, as shown in Fig. 7. The OKMs corresponding to EIS are represented according to step 2 of Procedure 1. Suppose that the OKMs are $\mathcal{W}_1^o$, $\mathcal{W}_2^o$, and they are conducted the union operation. Then they will be taken as operands of an OKM multiple set operation expression during the evaluation process.

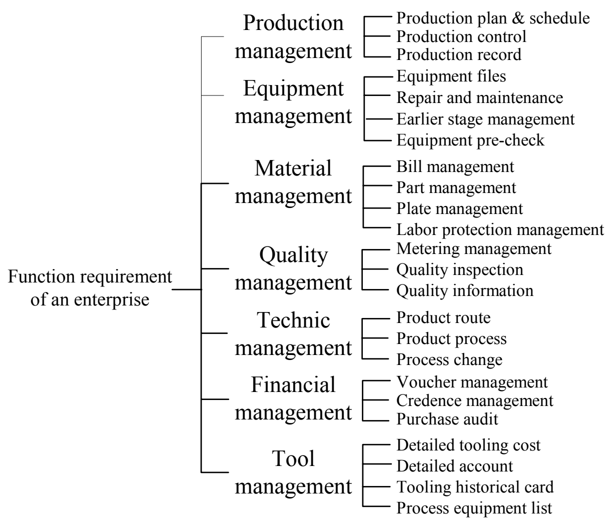


Fig. 7 Function requirement layering

Following step 3 and step 4 of Procedure 1, the OKMs are evaluated and the function-satisfaction degree vectors for the OKMs are obtained. The final function-satisfaction degree and the multiple function-satisfaction degree for OKM $\mathcal{W}_1^o$ are

$$\boldsymbol{h}_1^{\boldsymbol{L}} = \boldsymbol{w}^{\boldsymbol{L}}\left(\underset{\sim}{\boldsymbol{H}_1}\right)^T = (0,0,0.6594,0,0.6857,0,0.6535),$$

$\left(\boldsymbol{h}_{w1}^{\boldsymbol{L}}\right)^* = (0,0,1,0,1,0,1)$, respectively.

In the same way, other OKMs $\mathcal{W}_2^o$, $\mathcal{W}_3^o$ and $\mathcal{W}_4^o$ are evaluated as follows.

$$\boldsymbol{h}_2^{\boldsymbol{L}} = \boldsymbol{w}^{\boldsymbol{L}}\left(\underset{\sim}{\boldsymbol{H}_2}\right)^T = (0.832,0,0,0.642,0,0.71,0.538),$$

$\left(\boldsymbol{h}_{w2}^{\boldsymbol{L}}\right)^* = (1,0,0,1,0,1,1)$.

$$\boldsymbol{h}_3^{\boldsymbol{L}} = \boldsymbol{w}^{\boldsymbol{L}}\left(\underset{\sim}{\boldsymbol{H}_3}\right)^T = (0,0.751,0,0.542,0.496,0,0.816)$$

, $\left(\boldsymbol{h}_{w3}^{\boldsymbol{L}}\right)^* = (0,1,0,1,1,0,1)$.

$$\boldsymbol{h}_4^{\boldsymbol{L}} = \boldsymbol{w}^{\boldsymbol{L}}\left(\underset{\sim}{\boldsymbol{H}_4}\right)^T = (0.685,0,0.579,0.785,0,0.573,0)$$

, $\left(\boldsymbol{h}_{w4}^{\boldsymbol{L}}\right)^* = (1,0,1,1,0,1,0)$.

Following step 5 of Procedure 1, the OKM multiple set operation expressions are optimized by the developed optimization software based on Algorithm 1. The best OKM multiple set operation expression is $((\mathrm{M}_2 \text{-} (\mathrm{M}_1 + \mathrm{M}_3)) + \mathrm{M}_0) \text{-} \mathrm{M}_3$, with best fitness vector {0.832, 0.751, 0.6594, 0.785, 0.6857, 0.71, 0.816}.

We can see that after the reconfiguration of OKM, user satisfaction degree is improved compared with the original OKMs, because functions are more richened. If there are more OKMs in reconfiguration, the more complex final evaluation results will be obtained, and this will be helpful for the decision making on the reconfigured OKMs.

V. CONCLUSIONS

In this paper, the optimization of EIS is studied based on OKM and binary tree. Based on the user function requirements of OKM and the optimization of the OKM multiple set expressions, optimization problem of EIS aiming at maximum user satisfaction is solved. As is verified, the method proposed can help the enterprise select the optimal combination of EIS, thus, the enterprise can obtain the most suitable EIS for its own needs.

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