Research on Approximate Reconfiguration of Enterprise Information System based on Formal Representation

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***Abstract*—This paper deals with a new approach to formal representation and approximate reconfiguration of enterprise information system (EIS) based on object-based knowledge mesh (OKM) and information transfer relationship mesh (ITRM). To this end, new concepts of OKM and ITRM as well as their formal descriptions are proposed. Then, taking into consideration the approximation of modules in EIS, the reconfiguration element is defined, including its approximate matching degree. Furthermore, based on the operations of OKM and its approximate measurement, the formal representation method of information systems, reconfiguration algorithms based OKM and approximate matching, and mapping relationships between OKM and the information system, are explored. The rules in the reconfiguration and pre-processing rules are also studied. Finally, the approximate reconfiguration method based on OKM and ITRM is exemplified by the reconfiguration of the management information system (MIS) software used by an enterprise, which indicates the method to be very effective.**

***Index terms*—Object-based knowledgeable mesh, Information Transfer Relationship Mesh, Approximate Reconfiguration, Reconfiguration Rules**

I. INTRODUCTION

With the development of science and technology, various information systems began to appear, and thereafter 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. To date, no information system exits containing all of the functions suitable for all kinds of enterprises. On the other hand, although these information systems vary, they share several similarities; the only difference lies on the application field of information systems and the special realization of information systems. However, should information systems be developed independently, this may lead to repetitive development of identical modules, thus resulting in the wastage in manpower and material resources. Therefore, it is necessary to study the reconfiguration of information systems.

Thus far, the corresponding research effort[3~5] can be summarized as according to the following: (1) Studies on the reconfigurable properties of information systems; (2) Studies on the different aspects of information systems in reconfiguration; (3) Different technologies in the reconfiguration of EIS; and (4) Studies on the design and realization of information system reconfiguration. At present, studies on the reconfiguration of EIS have remained limited, let alone approximate reconfiguration based on formal methods.

The rich connotation of information systems is a kind of knowledge, which can be represented by knowledge mesh (KM)[6~9]. However, it is necessary to further the representation method of KM in order to tackle the information explosion. Fortunately, object-oriented method is a possible way to avoid information explosion in the knowledge representation of information systems. Therefore, an object-based knowledge mesh (OKM) is proposed [9], combining object-oriented technologies and knowledge mesh theory, realizing the formal representation of information systems, software systems and manufacturing modes, and solving information explosion in the representation by KM.

This paper studies the reconfiguration of EIS by formally representing them (i.e., OKM and ITRM), approximately reconfiguring them through multiple set operations, and mapping them into new information systems—a new representation and reconfiguration approach to EIS.

II. RELATIVE DEFINITIONS OF APPROXIMATE RECONFIGURATION

Enterprise information system is a complicated body of

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knowledge and cannot easily be represented either by symbolic or connection doctrine. However, it can be represented by a mesh known as KM. To solve the information explosion of formal representation by KM, OKM is proposed, whose formal definition can be seen in reference [9]. To measure the approximation and reconfigure them, the following definitions related to reconfigurations and approximations are given.

Definition 1. Reconfiguration element. The basic elements in reconfiguration are called reconfiguration element, and they include atom knowledge point element and relationship element.

Definition 2. Atom knowledge point function-matching degree $SG\left(E_1^P, E_2^P\right)$

Suppose the function of atom knowledge point element E_1^P is $\left\{e_{11}^p, e_{12}^p, \cdots, e_{1m}^p\right\}$, and the function of atom knowledge point element E_2^P is $\left\{e_{21}^p, e_{22}^p, \cdots, e_{2n}^p\right\}$, atom knowledge point function-matching degree is defined as follows:

$$SG\left(E_1^P, E_2^P\right) = \frac{b}{b + \sum_{s_1=1}^{m} f_s\left(e_{1s_1}^p\right) + \sum_{s_2=1}^{n} f_s\left(e_{2s_2}^p\right) - 2 f_t\left(E_1^P, E_2^P\right)}$$

where, $f_s\left(e_{1s_1}^p\right) = \begin{cases} 0 & \alpha^p = 0 \\ 1 & \alpha^p \neq 0 \end{cases}$, $f_s\left(e_{2s_1}^p\right) = \begin{cases} 0 & \alpha^p = 0 \\ 1 & \alpha^p \neq 0 \end{cases}$, α^p is the multiple function number of knowledge point function; $f_t\left(E_1^P, E_2^P\right)$ is the common function number of the two knowledge points; b is the adjusting coefficient of function-matching degree; m is the function number of knowledge point element E_1^P; n is the function number of knowledge point element E_2^P.

Definition 3. The layer of comprehensive knowledge point. The layer of sub-OKM used to represent the comprehensive knowledge point is called the layer of the comprehensive knowledge point. The root knowledge point is in 0th layer.

Definition 4. The approximation of comprehensive knowledge point PP_1^q, PP_2^q:

If $\exists E_1^p \in PP_1^q$ and $E_2^p \in PP_2^q$ satisfies $SG\left(E_1^P, E_2^P\right) > \theta$, then comprehensive knowledge points PP_1^q, PP_2^q is similar. If $\forall E_1^p \in PP_1^q$ and $E_2^p \in PP_2^q$ do not satisfy $SG\left(E_1^P, E_2^P\right) > \theta$, then comprehensive knowledge points PP_1^q, PP_2^q is dissimilar. Herein, E_1^p, E_2^p is the atom knowledge point included by comprehensive knowledge point, and θ is the given threshold.

Definition 5. Information flow matching degree of relationship element $SX\left(L_1, L_2\right)$

If the information flow of relationship element L_1 is $\left\{x_{11}, x_{12}, \cdots, x_{1m_l}\right\}$, and the information flow of relationship element L_2 is $\left\{x_{21}, x_{22}, \cdots, x_{2n_l}\right\}$, then the information flow matching degree of relationship element is defined as

$$SX\left(L_1, L_2\right) = \frac{g}{g + \sum_{k_l=1}^{m_l} f_{s_l}\left(x_{1k_l}\right) + \sum_{k_l'=1}^{n_l} f_{s_l}\left(x_{1k_l'}\right) - 2 f_t^l\left(L_1, L_2\right)}$$

where, $f_{s_l}\left(x_{1k_l}\right) = \begin{cases} 0 & \alpha_{1k_l} = 0 \\ 1 & \alpha_{1k_l} \neq 0 \end{cases}$, α_{1k_l} is the multiple information number of information flow x_{1k_l}; $f_t^l\left(L_1, L_2\right)$ is the common information flow number of the two relationship elements; g is the adjusting coefficient of information flow matching degree; m_l is the information flow number of relationship element L_1; and n_l is the information flow number of relationship element L_2.

Definition 6. Relationship element matching degree

If the relationship element L_1 connects two knowledge points E_1^P and E_2^P, and the relationship element L_2 connects two knowledge points E_3^P and E_4^P, then the relationship element matching degree is defined as

$$SL(L_1, L_2) = \begin{cases} \lambda_1 \max\left\{SG\left(E_1^P, E_3^P\right), SG\left(E_1^P, E_4^P\right)\right\} \times \\ \quad \max\left\{SG\left(E_2^P, E_3^P\right), SG\left(E_2^P, E_4^P\right)\right\} + \lambda_2 SX\left(L_1, L_2\right) \\ \qquad SG\left(E_1^P, E_2^P\right) \geq \theta \text{ and } SG\left(E_3^P, E_4^P\right) \geq \theta \\ 0 \qquad \text{others} \end{cases}$$

where, λ_1 is the knowledge point matching degree coefficient connected by relationship element; λ_2 is the information flow matching degree coefficient, and $\lambda_1 + \lambda_2 = 1$, λ_1, λ_2 are nonnegative; $SG\left(E_1^P, E_3^P\right)$, $SG\left(E_1^P, E_4^P\right)$, $SG\left(E_2^P, E_3^P\right)$ and $SG\left(E_2^P, E_4^P\right)$ are matching degree of knowledge points; θ is threshold; and $SX\left(L_1, L_2\right)$ is the information flow matching degree of the relationship element.

III. Approxmate Reconfiguration Of Enterprise Information System

Known from the KM theory[6~9], an enterprise information system consists of certain functions, each of which is composed of small functions which in turn are composed of even smaller functions, and so on, with various relationships existing among them. Therefore, if each function is viewed as an agent, any information system can be taken as an agent mesh (AM). To realize the reconfiguration of information system, EIS should firstly be formally represented by OKM. Then, according to the reconfiguration operations of OKM and ITRM, the reconfiguration of OKM and ITRM is realized, and then they are mapped into the new EIS, hence realizing the reconfiguration of EIS. In particular, EIS are reconfigured through a kind of AM → OKM and ITRM → new OKM and ITRM → new EIS, a new way to formally reconfigure EIS. Therefore, EIS reconfiguration is composed of three parts: (1) formal representation; (2) reconfiguration operations of OKM and ITRM based on matching degree; and (3) mapping from OKM and ITRM to new EIS.

In the formal representation of information system by OKM, information systems are represented by OKM and ITRM, and the KM (which is used to represent system in the formal representation by KM) is used to represent function modules, which can be referred in reference [9].

Algorithm 1. Reconfiguration algorithm of OKM without comprehensive knowledge point

Step1. Obtain the multiple sets of the OKMs and conduct a unitary process;

Step2. Perform the mixed operation of multiple sets according to the defined operations and operation priority, and obtain the new multiple set;

Step3. Pre-process operated multiple sets according to the preprocessing rules, and the pre-processing rules of OKM are similar to those of KM which can be referred to for reference [9], and the pre-processing rules of ITRM are Rule 2;

Step4. Map the new multiple sets into the corresponding OKMs.

Algorithm 2. Approximate reconfiguration algorithm of OKM with comprehensive knowledge point

Step1. Obtain the comprehensive knowledge point sets and their multiple sets of operated OKMs (OKM1 and OKM2), and conduct a unitary process;

Step2. For i=maxlayer1；i>0; i--

Obtain comprehensive knowledge point set $SP^q(i)$ in the i[th] layer of OKM1, then loop;

For time1=1；time1<=m1（i）；time1++

{

For j=maxlayer2；j>0; j--

{According to the definition of comprehensive knowledge point (Definition 6), judge the approximation of comprehensive knowledge point in OKM1 and comprehensive knowledge point in j[th] layer of OKM2. If they are approximate, then reconfiguration is conducted according to Algorithm 1, and new comprehensive knowledge points are obtained. Otherwise, reconfiguration is conducted according to Rule 1(3). }

Perform reconfiguration operations on all comprehensive knowledge points in upper layers corresponding to the approximate ones, and obtain the new multiple set of comprehensive knowledge point set and function set of the new OKM;

}

Step3. In the same way, perform ergodicity on the atom knowledge points of OKM1, and match with comprehensive knowledge points of OKM2. If they are approximate, then reconfiguration is conducted according to Rule 1(4), and new comprehensive knowledge points are obtained. Otherwise, reconfigure them as different knowledge points;

Step4. Obtain the atom knowledge point sets and their multiple sets of OKM1 and OKM2, and conduct a unitary process. Their function-matching degrees are obtained, and if matched, reconfigure them and obtain the new atom knowledge point set and the function set of OKM. Otherwise, reconfigure them as different atom knowledge points;

Step5. Obtain the complex relationship, information relationship, and the multiple set of the two OKMs, and according to the definition of relationship element approximation, judge approximation of complex relationship and information relationship. Then reconfigure the relationship element and obtain the new complex relationship, information relationship, and their multiple set of operated OKM;

Step6. Obtain the ITRMs between OKM1and OKM2

For i=maxlayer1；i>0; i--

Obtain ITRM set $OR^q(i^{'})$ between comprehensive knowledge point set $SP^q(i)$ in the i[th] layer of OKM1, then loop;

For ctime1=1；ctime1<=cm1($i^{'}$)；ctime1++

{

For j=maxlayer2；j>0; j--

{According to Definition 4, obtain the ITRMs between the approximate comprehensive knowledge points, judge the approximation of ITRM. If they are approximate, then reconfiguration is conducted according to Rule 1(5) and Algorithm 3, and new ITRMs are obtained. Otherwise, reconfiguration is conducted according to Rule 1(6).}

Perform reconfiguration operations on all

ITRMs between comprehensive knowledge points in upper layers corresponding to the approximate ones, and obtain the new ITRM of the new OKM;

}

Step7. Pre-process operated multiple sets of OKM according to the pre-processing rules;

Step8. Pre-process operated multiple sets of ITRM according to the pre-processing rules;

Step9. Map the new multiple sets into the corresponding OKMs and ITRMs.

Algorithm 3. Reconfiguration algorithm of ITRM

Step1. Obtain the ITRMs between OKMs according to the requirement of the reconfiguration;

Step2. Obtain the ITRMs and their multiple sets, and conduct a unitary process;

Step3. Perform the mixed operation of multiple sets according to the defined operations and operation priority, and obtain the new multiple set of ITRMs;

Step4. Pre-process operated multiple sets according to the pre-processing rule;

Step5. Map the new multiple sets into the corresponding ITRMs between OKMs.

Rule 1. Rules in approximate reconfiguration

(1) If the knowledge points (comprehensive and atom knowledge points) included by the comprehensive knowledge point are approximate, then the two comprehensive knowledge points are approximate, and reconfigure them as the matched knowledge points.

(2) If two comprehensive knowledge points are approximate, their upper layered comprehensive knowledge points are approximate as well, and corresponding operations are performed as matched ones.

(3) If two knowledge points are not approximate, then they are reconfigured as different knowledge points.

(4) If comprehensive knowledge point and atom knowledge point are approximate, then the atom knowledge point is reconfigured into comprehensive ones, and new comprehensive knowledge point can be obtained. If there are upper layered comprehensive knowledge points, then their upper layered knowledge points should also be reconfigured.

(5) If the two pairs of comprehensive knowledge points corresponding to ITRM are approximate, then the ITRMs are approximate, and can be reconfigured as matched ones.

(6) If only one pair of comprehensive knowledge points corresponding to ITRM is approximate, then the ITRMs are not approximate, and cannot be reconfigured as matched ones.

The pre-processing rules of ITRM are as follows, which is different to those of OKM.

Rule 2. Pre-processing rules of ITRM

(1) If the input and output knowledge points of ITRM are unchanged after multiple set operations, then ITRM can be mapped directly.

(2) If the input knowledge points of ITRM are unchanged after multiple set operations, and the output knowledge points decrease or disappear, then the relationships between decreased knowledge point and OKM should be a minus operation.

(3) If the output knowledge points of ITRM are unchanged after multiple set operations, and the input knowledge points decrease or disappear, then the relationships between decreased knowledge point and OKM should be a minus operation.

(4) If there are new input and output knowledge points of ITRM, then the relationships between new knowledge point and OKM should be added, and new ITRMs between OKMs should be constructed.

Mapping the reconfigured OKM and ITRM into the new EIS is the realization of EIS reconfiguration, and is the application of approaches, which can be referred in reference [6].

IV. EXAMPLES

The application of the approximate reconfiguration of EIS based on OKM method is explained in the case of the simplified MIS of a plant. Suppose the plant has information system 1, as a recombination of the plant, there is another information system 2, and to fully utilize the resource, information systems will be reconfigured. In this case, two information systems both include the management of system, production, quality, equipment and financial management module. In contrast with information system 2, information system 1 includes supply management module, but does not include material management module. In addition, there are approximate modules in them (e.g., both of them include production management modules, but their sub-modules are somewhat different), and there is also a module having different functions (e.g., equipment management module). According to the approximate reconfiguration of EIS based on OKM and ITRM, this reconfiguration is firstly in system level, with two information systems being formally represented into two OKMs and their ITRM, shown in Figs. 1 and 2.

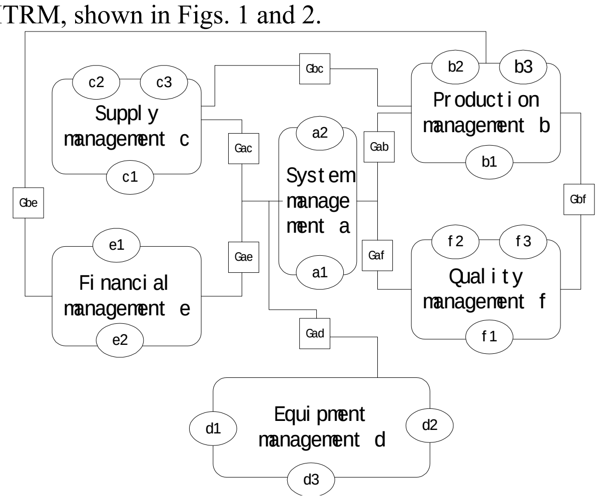

Fig. 1 OKM corresponding to Information System1

In Figs. 1 and 2, information systems are represented as two OKMs. In the OKMs, there are six comprehensive knowledge points, which can also be represented as six sub-OKMs.

According to the reconfiguration requirement, the two systems should be union. According to the reconfiguration operations, taking production management sub-OKM as an example, the sub-OKMs and their multiple set are as follows:

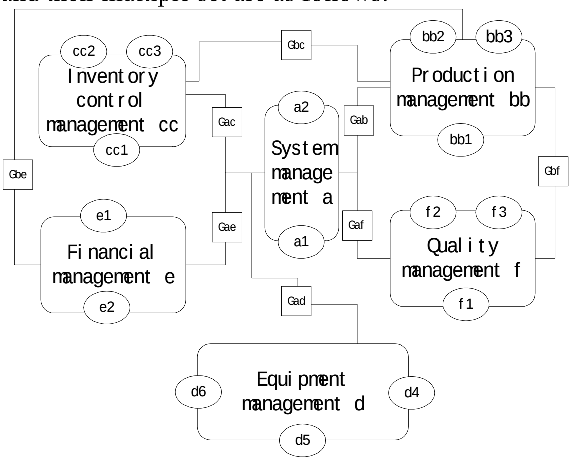

Fig. 2 OKM corresponding to Information System 2

Wb1=WMb1={b1, b2, b3, b11, b12, b13, b21, b22, b23; (b1, b11), (b1, b12), (b1, b13), (b2, b21), (b2, b22), (b2, b23); (b1, b3), (b2, b3) }

Wbb2=WMbb2={bb1, bb2, bb3, bb11, bb12, bb13, bb21, bb22, bb23, bb31, bb32, bb33; (bb1, bb11), (bb1, bb12), (bb1, bb13), (bb2, bb21), (bb2, bb22), (bb2, bb23), (bb3, bb31), (bb3, bb32), (bb3, bb33); (bb2, bb3) }

According to definitions of approximate matching degree, the matching degrees of knowledge point and relationship element are obtained so as to union the approximate element. The new production management sub-OKM multiple set can be obtained and mapped into new sub-OKM as follows.

Wbn＝{b1, b2, b3, bb2, b11, b12, b13, b21, b22, b23, bb21, bb22, bb23; (b1, b11), (b1, b12), (b1, b13), (b2, b21), b2, b22), (b2, b23), (bb2, bb21), (bb2, bb22), (bb2, bb23); (b1, b3), (b2, b3), (b1, bb2) }

In the same way, the ITRM between OKMs can be reconfigured, and new ITRMs can be obtained, while other function modules can be approximately reconfigured. Then, the new information system can be obtained. After reconfiguration, the new information system has the advantages of the two former two ones. Not being the simple union of the two, a completely new information system is formed. The new system runs effectively after the reconfiguration, which verifies that the reconfiguration of EIS can be realized through the approximate reconfiguration of OKM and ITRM. In this way, the repetitive development of identical module is avoided, and manpower and material resources are saved.

V. CONCLUSIONS

To solve the information explosion of KM method and to realize the approximate reconfiguration of EIS, this paper investigated a new formal method for the approximate reconfiguration of EIS (i.e., OKM approach). Based on the approximate reconfiguration operations of OKMs and IRTMs, as well as the matching degree definitions of reconfiguration elements, the approximate reconfiguration approach to EIS is proposed. Combined with transforming the practical information system to AM, as well as AM to OKM, and mapping the relationship of OKM to information system, the reconfiguration of EIS based on formal method can be realized.

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REFERENCE

[1] Kauffman, R. J., Clemons, E. K., and Dewan, R. M., “Information systems in competitive strategies: Offshoring, risk management, strategic pricing, e-sourcing, and standards,” *Journal of Management Information Systems*, Vol. 22, pp. 7-14, 2005.

[2] Ivanov, D. A., Sokolov, B. V., and Kaeschel, J., “Structure dynamics control-based framework for adaptive reconfiguration of collaborative enterprise networks,” *International Journal of Manufacturing Technology and Management*, Vol. 17, pp. 23-41, 2009.

[3] Lee, Y. L., Hwang, S. L., and Wang, E. M., “An integrated framework for continuous improvement on user satisfaction of information systems,” *Industrial Management and Data Systems,* Vol. 106, pp. 581-595, 2006.

[4] Li, C. B., and Zhang, L., “Risk evaluation of information system based on grey and fuzzy comprehensive method,” *Journal of Computational Information Systems,* Vol. 5, pp. 1705-1712, 2009.

[5] Lemmon, M., He, K. X., and Shatz, S., “Dynamic reconfiguration of software objects using Petri nets and network unfolding,” *Proceedings of the IEEE International Conference on Systems, Man and Cybernetics,* pp. 3069-3074, 2000.

[6] Xue, C. G., and Yan H. S., “The study on self-reconfiguration of knowledge webs based on agent webs,” *Computer Integrated Manufacturing Systems,* Vol. 9, pp. 995-1000, 2003.

[7] Yan, H. S., “A new complicated-knowledge representation approach based on knowledge meshes,” *IEEE Transactions on Knowledge and Data Engineering,* Vol. 18, pp. 47-62, 2006.

[8] Xue, C. G., and Yan, H. S., “A study on self-reconfiguration of a knowledgeable manufacturing system,” *Proceedings of the Institution of Mechanical Engineers, Part B：Journal of Engineering Manufacture,* Vol. 218(B11), pp. 1601-1617, 2004.

[9] Cao, H. W., and Xue, C. G., “Formal representation approaches to enterprise information system: From KM to OKM,” *International Conference on Information Engineering and Computer Science,* , pp. 1436-1439, 2009.

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