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ABSTRACT

Compared with traditional information system development methodology, COTS-based information system has the following advantages: Avoid expensive development and maintenance; frequent upgrades often anticipate organization's need; rich functionality; mature technologies; tracks technology trends, etc. However, how to select appropriate COTS components is a complex problem. For improving the accuracy of decision-making in COTS component procurement, a two-period model is put forward. In the first period, the procurement requirement of each COTS component is compared with a COTS component case base by case-based retrieval (CBR) and the initial candidates are selected. In the second period, a (0-1) integer goal programming model is created to optimize cost and time of the whole COTS-based system, and help decision makers to decide the final candidates. Case shows that the two-period method declines the complexity of computation and increases the rationality of decision.

Keywords: COTS (Commercial Off-The-Shelf), component procurement, case-based retrieval, goal programming

0 INTRODUCTION AND BACKGROUND

COTS（Commercial Off-The-Shelf）component is a kind of software product that has the following characteristics [1]:

- Sold, leased, or licensed to the general public;
- Offered by a vendor trying to profit from it;
- Supported and evolved by the vendor, who retains the intellectual property rights;
- Available in multiple, identical copies;
- Used without source code modification.

Compared with traditional information system development methodology, COTS-based solution has the following advantages: Avoid expensive development and maintenance; frequent upgrades often anticipate organization's need; rich functionality; mature technologies; tracks technology trends, etc [2].

A lot of organizations and scholars have done a series of research on COTS component in recent years. The European Union's Framework V programme has funded a series of new research initiatives in component-based software engineering (CBSE) [3]. Gardler et al. [4] research how to support component-based software evolution at strategic level of e-Business. Maiden et al. [5] discuss how to acquire COTS software selection requirements. Some scholars give guidance about COTS component evaluation and selection [6,7,8]. Sundarraj et al. [9] create a multi-period optimization model for the procurement of component-based enterprise information technologies.

The optimization model for the procurement of COTS component given by Sundarraj considers both component procurement cost and inter-component integration cost. That makes decision more scientific. However, the model cannot explain how to deal with the attributes difficult to be described quantitatively. In this paper, the kind of attribute is considered and a two-period decision model for COTS component procurement is given. In the first period, initial candidates are selected by case-based retrieval (CBR). In this period, the procurement requirement of each COTS component is viewed as a new problem and is compared with a COTS component case base. Of course, a COTS component case base should be created in advance by collecting information from component marketplace and scoring attributes for each COTS component. In the second period, final candidates are selected by (0-1) integer goal programming from initial candidates.

1 COTS-BASED SOFTWARE SYSTEM

A COTS-based software system means that the software system is developed by purchasing and integrating COTS components. Compared with traditional system, a COTS-based software system has longer analysis and design phases, whilst the implementation phase focuses on COTS component integration rather than on programming [4]. In implementation phase, the main task is inter-component integration. The glue code programming averagely is 37% of effort required to complete various COTS-based development activities [10].

A process model [4] for developing COTS-based e-Business system is shown in Figure 1.

E-Business Maturity Model (EBMM) is a strategic positioning and planning tool. Pattern library stores software patterns mapping business patterns that represent e-business "best-practice" processes. In analysis and design phase, EBMM is applied to export business patterns mapping business strategy and pattern library is used to export software patterns mapping business patterns. After analyzing the software patterns, component procurement requirements are acquired. In implementation phase, according to requirements, components are tested and purchased, and then, system is developed by components integration.

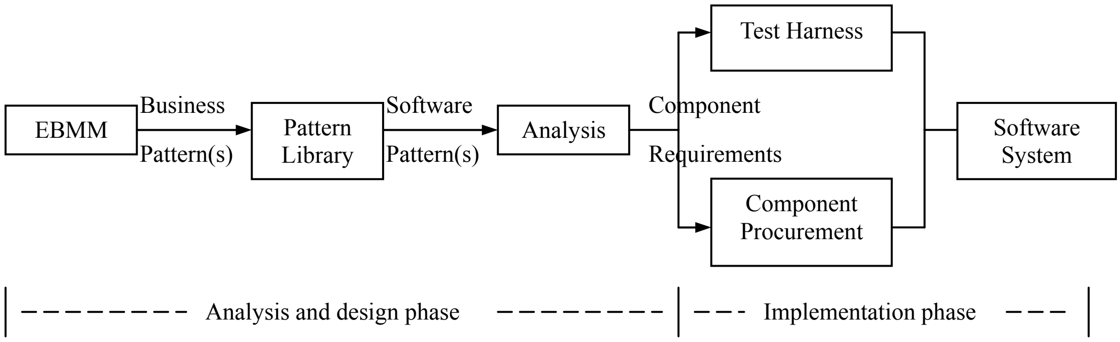

Figure 1 Process model for developing COTS-based e-Business system

In this paper, the work mainly focuses on the component procurement decision activity in implementation phase. On the basis of component requirements, CBR and goal programming are applied to create a two-period decision model.

The details about the model are given in Section 2.

2 MODEL

COTS component procurement decision-making is a complex process. In the process, large numbers of attributes should be considered comprehensively. Some attributes are shown in table 1.

Table 1 The attribute of COTS component

Category	Attribute
Technical	Application domain
	Architecture level
	Architecture compatibility
Quality	Functionality
	Reliability
	Usability
	Efficiency
	Maintainability
	Portability
	Effectiveness
	Productivity
	Safety
	Satisfaction
Vendor	Capability maturity level
	Market share
	Market size
	Market stability
	Financial viability
	Management viability
	R&D viability
	Product support
	Vendor reputation
	Training
	Delivery time
	License type
Cost	Acquisition cost
	Ownership cost

According to whether easy to be described quantitatively, attributes are categorized into two groups: quantitative ones and non-quantitative ones. Quantitative attributes, such as cost and time, satisfy additivity principle and are easy to get solution by goal programming. Non-quantitative attributes, such as functionality, are non-additivity and not easy to be applied to goal programming. In this paper, CBR is used to aggregate the non-quantitative attributes.

In section 2.1, the method how CBR is applied to candidate selection is introduced in detail. In section 2.2, the goal programming model is given.

2.1 CBR(Case-Based Retrieval)

Nowadays, there is no uniform and accepted approach for COTS component procurement decision-making. We find that selecting components from marketplace is similar to retrieving components from case base in principle. So, CBR is applied and a nearest neighbor retrieval function is given as formula (1) shows[11]:

$$\frac{\sum_{i=1}^{n} W_i \times \mathrm{sim}\left(f_i^{\mathrm{I}}, f_i^{\mathrm{R}}\right)}{\sum_{i=1}^{n} W_i} \tag{1}$$

Where W_i is the weight of attribute i, sim( ) is similarity function, and f_i^{I} and f_i^{R} are the values for the attributes of the input and retrieved cases. The retrieved case with a higher aggregate match score represents the nearer match.

Initial candidates are selected from COTS marketplace according to the threshold β defined in advance.

2.2 Goal Programming

Integer goal programming is applied to select the final candidates from initial candidates. Two main quantitative objectives, cost and time, are considered.

The total cost of a COTS component is made up of acquisition cost and ownership cost. Acquisition cost includes price and procurement expense. Ownership cost mainly includes inter-component integration cost.

The total Time is composed of delivery time and inter-component integration time.

The (0-1) integer goal programming model is given as follows:

$$\text{Min } w_1 v_1 + w_2 v_2$$

s.t.

$$\sum_{j=1}^{J_i}\sum_{i=1}^{I}\left(p_i^j + e_i^j\right)x_i^j + \frac{1}{2}\sum_{j'\neq j''}\sum_{i'\neq i''} c_{i'i''}^{j'j''} x_{i'}^{j'} x_{i''}^{j''} - v_1 = c_{min}$$

$$\sum_{j=1}^{J_i}\sum_{i=1}^{I} t_i^j x_i^j + \frac{1}{2}\sum_{j'\neq j''}\sum_{i'\neq i''} t_{i'i''}^{j'j''} x_{i'}^{j'} x_{i''}^{j''} - v_2 = t_{min}$$

$$\sum_{j=1}^{J_i} x_i^j = 1 \quad \text{for all} \quad i \in I$$

$$\sum_{j=1}^{J_i} x_{i'}^{j'} = 1 \quad \text{for all} \quad i' \in I$$

$$\sum_{j=1}^{J_i} x_{i''}^{j''} = 1 \quad \text{for all} \quad i'' \in I$$

$$x_i^j, x_{i'}^{j'}, x_{i''}^{j''} \in \{0,1\}$$

$$v_1, v_2 \geq 0$$

$$w_1, w_2 \geq 0$$

Notation: p_i^j is the price of candidate component M_i^j; e_i^j is the procurement expense of component M_i^j; $c_{i'i''}^{j'j''}$ is the integration cost of component $M_{i'}^{j'}$ and component $M_{i''}^{j''}$; t_i^j is the delivery time of component M_i^j; $t_{i'i''}^{j'j''}$ is the integration time of component $M_{i'}^{j'}$ and component $M_{i''}^{j''}$; *i*, *i'*, *i''*∈*I*; *I* is the set of component requirement areas that needed to be covered; *j*, *j'*, *j''*∈J_i, J_i is the set of candidate components for component requirement area *i* (*i*∈*I*);

$$x_i^j, x_{i'}^{j'}, x_{i''}^{j''} = \begin{cases} 1, & if \quad M_i^j, M_{i'}^{j'}, M_{i''}^{j''} \quad is \quad selected \\ 0, & otherwise \end{cases};$$

v_1, v_2 is the eccentricity coefficient; w_1, w_2 is the weight of v_1, v_2; c_{min} is the limitation of total cost; t_{min} is the limitation of total time.

3 EXAMPLE

Assume that company *H* has three COTS component requirement areas: *A*, *B*, and *C*. The inter-component integration relationship is *A*→*B*→*C*. Namely, *A* links with *B* and *B* links with *C*. The candidate set of *A* is {*A*1, *A*2, *A*3}. The candidate set of *B* is {*B*1, *B*2, *B*3}. The candidate set of *C* is {*C*1, *C*2, *C*3}.

In the first period, initial candidates are selected by CBR.

The similarity function is defined as formula (2).

$$\text{sim}\,(f_i^{\text{I}}, f_i^{\text{R}}) = 1 - \left| f_i^{\text{I}} - f_i^{\text{R}} \right|, f_i^{\text{I}}, f_i^{\text{R}} \in [0,1] \quad (2)$$

Because requirement areas are viewed as frame of reference to score, we can assume the values for attributes of each requirement area have been standardized, namely, $f_i^{\text{I}} \equiv 1$. Then, formula (2) can be simplified as formula (3).

$$\text{sim}\,(f_i^{\text{I}}, f_i^{\text{R}}) = f_i^{\text{R}} \quad (3)$$

The amount of attributes is large in practice. For simplifying computation, only four attributes—functionality, reliability, safety, product support degree— are considered in this example. In table 2, the values of attributes are given by score method.

Table 2 The values for attributes

	Functional-ity	Reliability	Safety	Product support degree
*A*1	1.0	0.9	0.9	0.9
*A*2	0.9	0.8	0.8	0.8
*A*3	0.8	0.8	0.7	0.6
*B*1	0.8	0.9	0.8	0.9
*B*2	0.9	0.9	0.9	0.9
*B*3	0.7	0.6	0.7	0.8
*C*1	0.8	0.8	0.9	0.9
*C*2	0.9	1.0	0.9	0.9
*C*3	0.9	0.8	0.9	0.8

The weights of four attributes are 0.4, 0.2, 0.2, and 0.2 in turn. The threshold β is 0.8. Input the data above into formula (1) and formula (3). The result shows that *A*3 and *B*3 should be removed from candidates. Therefore, *A* has two choices {*A*1, *A*2}; *B* has two choices {*B*1, *B*2}; and *C* still has three choices {*C*1, *C*2, *C*3}.

In the second period, final candidates are selected by (0-1) integer goal programming. The data in tables below is given by Delphi method.

Table 3 Inter-component integration cost (hundred $)

	*A*1	*A*2	*B*1	*B*2	*C*1	*C*2	*C*3
Price (hundred $)	65	75	20	18	45	40	43
Procurement expense (hundred $)	6.5	7.5	2	1.8	4.5	4	4.3
Delivery time (hour)	10	15	18	12	6	9	12

Table 4 Inter-component integration time (hour)

	*A*1	*A*2	*B*1	*B*2	*C*1	*C*2	*C*3
*A*1	0	0	3	2	0	0	0
*A*2	0	0	2.5	2.8	0	0	0
*B*1	3	2.5	0	0	2	1	2
*B*2	3	2.8	0	0	2	1.6	1.5
*C*1	0	0	2	2	0	0	0
*C*2	0	0	1	1.6	0	0	0
*C*3	0	0	2	1.5	0	0	0

Table 5 Price, procurement expense, and delivery time

	*A*1	*A*2	*B*1	*B*2	*C*1	*C*2	*C*3
*A*1	0	0	1	2	0	0	0
*A*2	0	0	1.5	0.8	0	0	0
*B*1	1	1.5	0	0	1	1.5	2
*B*2	2	0.8	0	0	1	0.8	1.5
*C*1	0	0	1	1	0	0	0
*C*2	0	0	1.5	0.8	0	0	0
*C*3	0	0	2	1.5	0	0	0

w_1=0.75, w_2=0.25, c_{min}=130, t_{min}=30.

Input data above into goal programming model and the result is v_1=8.9, v_2=3.8, $w_1v_1 + w_2v_2$=7.625. The final candidates— *A*1, *B*2, and *C*2— are purchased.

4 CONCLUSIONS AND EXTENSION

According to different features, the attributes of COTS component are categorized into quantitative ones and non-quantitative ones. To non-quantitative attributes, CBR is applied to aggregate the evaluation values. To quantitative attributes, goal programming is applied to decide the final candidates. The two-period method declines the complexity of computation and increases the rationality of decision. A series of extensions are possible with the work described in this paper. Firstly, the collection of data may be more scientific and the sensitivity of parameters should be analyzed. Secondly, for a large-scale system, the computing would be complex and efficient solution algorithms should be developed. Finally, the issues about decision support system aiding COTS component procurement decision-making are worth to be researched more deeply.

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