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Optimal component selection based on cohesion & coupling for component based software system under build-or-buy scheme

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ABSTRACT

Component based software system approach is concerned with the system development by integrating components. The component based software construction primarily focuses on the view that software systems can be built up in modular fashion. The modular design is a logical collection of several independent developed components that are assembled with well defined software architecture. These components can be developed in-house or can be obtained commercially from outside market making *build* versus *buy* decision an important consideration in development process. Cohesion and coupling (C&C) plays a major role in determining the system quality in terms of reliability, maintainability and availability. Cohesion is defined as the internal interaction of components within the module. On the other hand, coupling is the external interaction of the module with other modules i.e. interaction of components amongst the modules of the software system. High cohesion and low coupling is one of the important criteria for good software design. Intra-modular coupling density (ICD) is a measure that describes the relationship between cohesion and coupling of modules in a modular software system and its value lies between zero and one. This paper deals with the selection of right mix of components for a modular software system using build-or-buy strategy. In this paper, fuzzy bi-criteria optimization model is formulated for component selection under build-or-buy scheme. The model simultaneously maximizes intra-modular coupling density (ICD) and functionality within the limitation of budget, reliability and delivery time. The model is further extended by incorporating the issue of compatibility amongst the components of the modules. A case study is devised to explain the formulated model.

1. Introduction

Component based software system (CBSS) development is a promising solution for the development of large scale and complex systems. In contrast to CBSS, traditional development techniques for software development are suspected to have high development cost, low productivity, unmanageable software quality and high risk to move to new technology. CBSS provides efficient mechanism to significantly reduce development cost, time-to-market, improve maintainability; reliability and overall quality of software systems [19]. This approach has raised a remarkable amount of interests both in academia and software industry. The development of software system using CBSS approach facilitates the use of modularity where in each module is more controllable and developed by integrating components. The cost and quality of a modular software system are majorly affected by selection of suitable components. The developers have different options for the development of these small independent components such as choosing from available commercial-off-the shelf (COTS) components developed by different developers, in-house development from the scratch, or modifying the functioning of some existing in house components [10].

COTS (or in-house built) components tend to give higher quality software and enables the organization to have new technologies due to the fact that the development of these components finds advantage from the techniques such as design diversity, data diversity and environment diversity. COTS components are built by independent team of developers in different language and on different platform. They are relatively smaller in size and less complex and can be purchased from the various software developers in the market as standard components. Different versions of a COTS product are often available in the market with different specifications. With all these advantages of COTS, there are some risks which are associated in using the COTS products such as functional problems, security issues, compatibility issues, integration and interoperability issues, vendor issues, procurement and licensing issues and testing issues.

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The idea of building a component in-house comes when a completely customized job is required for the internal customer of an organization. There is always a tussle between build-or-buy decisions in software development. Making this kind of decision is more than just the comparison of relative prices and availability of the component. Other important parameters like reliability, delivery time and interactions amongst the components should also be considered. Build decision is usually preferable when technology is easily available and cheaper, reliability of available COTS component can not be trusted, available component may not be compatible with the proposed system architecture. Sometimes there are existing in-house components that can be reused by modifying them to adjust to the present requirements. Reusability of existing components gives cost and time advantage. However such components are also categorized as build components.

Efficiency of a component based software system depends largely on architecture of the system. Cohesion and coupling (C&C) plays a major role in determining the system quality in terms of reliability, maintainability and availability. Cohesion is an intra-module property. It is defined as degree to which all components of a module work together as a functional unit. High cohesion is desirable as it accounts for improved strength and quality of the module. Coupling on the other hand is an inter-module property. It is defined as the degree of interdependence between components among the modules. Tight coupling is an undesirable property in modular based software development. “intra-modular coupling density (ICD)” is a measure for describing the relationship between cohesion and coupling of modules in the design of an object oriented software system [7].

A CBSS adopts modular approach for software development to improve the flexibility and comprehensibility of software systems [21]. In past, some of the authors have attempted to define criteria and develop metrics for software modularity. In the past few years, some work has been done in the area of development of modular software system based on the criteria of minimizing the coupling and maximizing the cohesion of software modules [21,7,8,13]. Stevens et al. have proposed a software quality metrics of cohesion and coupling. A highly cohesive module exhibits high reusability and loosely coupled systems enable easy maintenance of a software system [23]. Optimization problems of optimum selection of COTS components are widely studied by many researchers in the literature ([2,4,5,12,14,16–20,26,28,31] Authors in their work have developed optimization models with the objectives of maximization of reliability or minimization of cost or some of them have kept budget as a constraint. Few of the authors have addressed the build-or-buy strategy for optimal component selection problem. An optimization framework for “build-or-buy” decisions in software architecture was proposed by Cortellessa et al. [10]. Very few authors so far have discussed the optimal component selection problem based on cohesion and coupling of the software system incorporating build-or-buy strategy.

In this paper, bi-criteria optimization model is formulated to carry out the optimal selection of components incorporating build-or-buy strategy for CBSS based on the objectives of maximization of ICD as well as functionality of the software system under the constraints of cost, reliability and delivery time. Development of software system using CBSS approach may cause incompatibility issues amongst the COTS components belonging to different modules. The issue of incompatibility must be resolved to smooth the progress of interaction amongst the components of different modules. The incompatibility is caused because of the COTS components, as they are purchased from different vendors from the software market which leads to problem such as integration, execution, interfacing, licensing, etc. keeping in view these problems the paper also addresses the issue of incompatibility.

The paper is organized as follows. In Section 2, we have reviewed the literature. In Sections 3 and 4, notations and assumptions of the formulated model are presented. Section 5 discusses various criteria for component selection in CBSS. In Section 6, mathematical problem is formulated. In Section 7, we describe the methodology and present fuzzy optimization model for selecting components. Section 8 discusses the case study of the manufacturing enterprise for which the solution is provided in Section 9. Finally in Section 10, we furnish our concluding remarks.

2. Literature review

Optimization problems of optimum selection of components are widely studied by many researchers in the literature for development of safe and reliable software systems. The models used basic information on components reliability, cost, development time and delivery time. Chi et al. [9] investigated the trade-off between system reliability improvement and resource consumption. Software reliability to cost relation is developed from software reliability related cost model and software redundancy models with common cause failures. Ashrafi and Berman [4] presented optimization models which address the trade-off between reliability and cost in development of large software packages that consists of several programs. The authors formulated models considering with and without redundancy. Jung and Choi [15] introduced two optimization models for the COTS selection in the development of modular software systems considering cost/reliability trade-off. They have also addressed the issue of incompatibility amongst the COTS components of the modules. Abreu and Goulao [7] presented a quantitative approach to measure and assess the solutions of software modularity based on the criteria of minimal coupling and maximal cohesion. The optimal component selection problem due to Kapur et al. [16] considers software built by assembling COTS components performing multiple functions. In their work they have discussed optimal reliability allocation for modular software systems. Shen et al. [24] developed a fuzzy optimization model for selecting the best COTS product in the development of a software system based on COTS. Sarkar et al. [22] presented an information theoretic metrics that measure the quality of modularization of a non-object software system. These metrics are tested on open-source systems of large legacy-code business applications. Neubauer and Stummer [20] presented a two phase decision support approach based on multiobjective optimization for the COTS selection. Zachariah and Rattihalli [29] used goal programming approach in multi-criteria optimization model for the COTS selection. Cortellessa et al. [10] developed an optimization framework to support “build-or-buy” decision which affects the software cost as well as the ability of the system to meet its other requirements in selecting software components. Cortellessa developed the model that treats component selection as a cost-minimization problem under delivery time and quality constraints. Jha et al. [14] have formulated an optimization model for COTS selection for a fault tolerant modular software system. Joint optimization models were formulated with the objective of reliability maximization and minimization of execution time of the software system under budgetary constraint. Kwong et al. [19] proposed a modified way of measuring the cohesion and coupling of software modules considering the function ratings of various software components for CBSS development. Kwong et al. [30] further designed the scheme of typical reuse mode wherein six reuse modes are addressed from the sequence of activities. Optimization model proposed in this paper helps in selecting a reuse scenario for minimizing cost, maximizing reliability and satisfying system constraints. Gupta et al. [12] introduced an interactive fuzzy approach for solving a multi-objective COTS selection model that provides a strategy for selecting optimal COTS