ABSTRACT

of
The Ph.D. Thesis entitled

OPTIMAL COMPONENT SELECTION FOR FAULT TOLERANT SOFTWARE DESIGN UNDER CONSENSUS RECOVERY BLOCK SCHEME

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With the advent of the computer age, computers, as well as the software running on them, are playing a vital role in our daily lives. We seldom see any industry or service organization working without the help of an embedded software system. Software is embedded in all kind of systems such as transportation, medical, telecommunications, military, industrial processes, entertainment and the list is almost endless. The continuously growing demand of large and complex software systems has introduced major challenges for the software developers’ viz. quality, cost effectiveness, reliability and delivery time of the software. Demand of large and complex systems on the other hand gave birth to Component Based Software Development (CBSD).

A component based software system is usually built up of multiple software modules such that each module is more manageable. Module design is identified during the development process and integrated later to form a complete system. The modular design is even further sub divided into smaller components such that these small components can be developed independently and later linked to develop a full functionality. The developers have different options for the development of these small independent components such as choosing from already available commercial off-the-shelf (COTS) components, in-house development, or modifying the functioning of some existing components. By using COTS components the productivity of development process is improved in terms of time, costs and reliability.

Reliability of computer systems has become a major concern for software industry. Techniques of fault avoidance and fault removal during the development phase allows the developers to build highly reliable software, however even then one can’t assure that the software would never fail in operational phase. There comes the need of software fault-tolerance techniques which enable a software system to tolerate software faults remaining in the system after it is put to use. Fault-tolerant software assures system reliability by using protective redundancy at the software level. The redundancy in software system can be created by adding build components, buy (COTS) component or by reusing and modifying the functionality of existing components. Improving software reliability using redundancy however requires additional resources. Therefore, it is necessary to carry trade-off between cost and reliability of the software system during its design phase. There are some structural methodologies for a fault-tolerant system such as the recovery block, N-version programming schemes. Another well-known mechanism is to use a hybrid fault
tolerant scheme, which combines the features of both RB and NVP mechanism and is known as consensus recovery block scheme. The basic mechanism of these schemes is to provide redundant software components to tolerate software failures.

The decision to choose right mix of components for a CBSD is not an easy task. It involves a trade-off between quality and cost along with many other concerns. Manager cannot take this decision based on his intuition, or the past experiences. He has to rely upon the scientific way of decision making. Mathematical modeling and optimization is the scientific field of Operational Research offers promising solution to this decision problem. Operational Research (OR) is the use of advanced analytical techniques to improve decision making. The branch of mathematics that consists of developing a mathematical model that is used to solve a real world problem is referred to as Mathematical Modeling. A mathematical model is an abstraction of the assumed real world, expressed in an amenable manner as mathematical functions that represent the behavior of the assumed systems. Optimization is a powerful tool of operational research and is regarded as an important methodology of conceptualization and analysis. The optimization models developed for component based software engineering allow managers to choose the best combination of components out of the various components available for a module in designing of a fault tolerant modular software system. Crisp and fuzzy optimization models for component selection are formulated in the thesis. In crisp optimization models, the parameters are deterministic and known. However, for many practical problems, the input information is imprecise and vague. This results in the use of fuzzy optimization method with fuzzy parameters. Crisp mathematical programming approaches provide no such mechanism to quantify these uncertainties. Fuzzy optimization is a flexible approach that permits more adequate solutions of real problems in the presence of vague information, providing the well-defined mechanisms to quantify the uncertainties directly. This thesis endeavors to apply techniques of Operational Research to modeling and optimization in component selection for a Component based software engineering for fault tolerant modular software systems under consensus recovery block scheme.

The thesis is organized in chapters as follows:

Chapter 1 : Introduction

Chapter 2 : Optimal Component Selection for COTS Based Modular Software System
Chapter 3 : Fuzzy Multi-Objective Approach to Component Selection for COTS Based Fault Tolerant Software System

Chapter 4 : Optimal Component Selection for Fault Tolerance Modular Software System using Build-or-Buy Policy under Fuzzy Environment

Chapter 5 : Fuzzy Multi-Objective Approach to Component Selection for COTS Based Modular Software System Incorporating Mandatory Redundancy for Critical Modules

Given below are the brief compositions of chapters:

Chapter 1 is an introductory chapter and gives a brief description of various concepts used in the thesis and literature survey. The topics included in section one are software engineering concepts, software development, life cycle process and methodology of component based software development. Fault tolerant techniques are also highlighted in this chapter. The second section reviews different optimization models in the literature for selection of components in design of a modular software system.

Chapter 2 Crisp optimization models for component selection of COTS based modular software system are developed in this chapter. This chapter focuses on development of COTS based software system. It is a system that has been built primarily by assembling a set of COTS software components. In section one, multi-objective optimization model is formulated for maximizing reliability and minimizing cost subject to various constraints on component selection for a fault tolerant modular software system. In section two, we have investigated a problem of component selection for a fault tolerant modular software system incorporating execution time. The execution time taken by the software to perform a function is important to a developer as well as user. Long execution time for performing a function may cause dissatisfaction and lead to low productivity of the system. The objective of the optimization models developed in this section is to select COTS components in such a way so that the reliability of the software system is maximum and the deviational execution time is minimum under the constraint of component selection and budget. The issue of compatibility of modules is also discussed in both the sections as it is observed that some alternatives of a module may not be compatible with alternatives of other modules due to problems such as implementation, interfaces, and licensing. Numerical illustrations are provided to demonstrate the developed models.
Chapter 3 introduces fuzzy multi-objective approach to component selection for COTS based modular software system. The model formulation for the previous chapter requires an estimate of reliability and cost/execution time for various alternative COTS in the modules. Due to the changing environment, these estimates cannot be determined definitely because cost, execution time and reliability are affected by ambiguous and uncertain factors which cannot be measured precisely. Under such conditions; making a decision based upon crisp model is not the best decision. Hence, we formulate fuzzy multi-objective optimization models for COTS software component selection based on imprecise aspiration levels, the decision maker may decide his aspiration levels on the basis of past experience and knowledge possessed by him. The problem is formulated for consensus recovery block fault tolerant scheme. In section one, we develop a fuzzy multi-objective optimization models for selecting COTS alternatives for modules with the dual objective of reliability maximization and cost minimization. Section two develops a fuzzy multi objective optimization model for selecting COTS components, based on maximization of system reliability and minimization of deviational execution time of the software under budgetary and other constraint on component selection. Issue of compatibility of modules is discussed in both the sections. Numerical illustrations are provided to demonstrate the models developed.

Chapter 4 In this chapter fuzzy optimization models are developed for component selection for a modular software system incorporating build-or-buy strategy. In chapter two and three we focused only on COTS based modular software system. But at times there may be a situation when the components with the desired requirements are not available in the commercial market or there may be a situation that a COTS component is available, but it is economical to develop that component in-house. In both the cases the developer will go for in-house built component. While developing software, components can be both bought as commercial off-the-shelf (COTS) products, and probably adapted to work in the software system, or they can be developed in-house. This decision is known as build-or-buy decision. Since various alternatives are available to the software developer, he has to choose the right mix of components for the system he is developing. In section one, a fuzzy multi-objective optimization model is formulated for the selection of the alternatives (in-house or COTS) for modules to maximize the system reliability by simultaneously minimizing the cost under delivery time constraint. In section two of this chapter we have further broke down the approach for selection of components. If a COTS alternative is selected, then different versions
are available for each alternative and only one version will be selected for each alternative of a module. If a component is an in-house-built component, then the alternative of a module is selected. The model also determines the optimal redundancy level of the modules of the software system so as to maximize reliability and minimize cost under the delivery time and other constraints on component selection for fault tolerant systems. Issue of compatibility of modules is discussed in both the sections. Numerical illustrations are provided to demonstrate the models developed.

Chapter 5 presents fuzzy multi-objective optimization models for selection of COTS components with mandatory redundancy for critical modules. There are some modules in a system where failures can result in significant economic losses, physical damage or threats to human life. These modules are usually called critical modules. Therefore, there is a need for developing a system with a built-in redundancy in the critical modules, so that if a particular component (alternative) in a module fails other one will take over and prevents the system from failure. In section one, a fuzzy multi-objective optimization model is developed for optimal component selection with the dual objective of reliability maximization and cost minimization of the overall system under the constraints on fault tolerance and criticality of modules. Section two aims at optimal selection of COTS components by minimizing the absolute deviational execution time and simultaneously maximizing the system reliability under the constraints on fault tolerance and criticality of modules using fuzzy approach. Finally in section three, mandatory redundancy for critical module has also been considered in designing fault tolerance system incorporating build-or-buy strategy under Consensus recovery block scheme.

Avenue for further research have been discussed in the conclusion given at the end of each Chapter. The research indicates component selection in designing a fault tolerant system is an important and rapidly evolving area of study.

This thesis is based on the following research papers in the order of appearance in the thesis:


Optimal Component Selection for Fault Tolerant Software Design under Consensus Recovery Block Scheme


