



Reliability Estimation of Component-Based Software through Interaction-Based Model

Dimpal Tomar¹, Dr. Pradeep Tomar²
School of Information and Communication Technology
Gautam Buddha University
Greater Noida, Uttar Pradesh
INDIA

Abstract: Software component technology has a great impact on the evolution of software development. The benefit of this technology, such as reusability, complexity management, time-effort reduction, and increased productivity, has been key drivers of its adoption by industry. One of the main issues in building component-based systems is to maintain quality in which reliability play a vital role. This paper proposes a methodology based on Interaction-Based Model to assess the reliability of overall Component-Based Software System (CBSS). This estimation of CBSS reliability from the reliabilities of individual components and average interaction reliability is a matter of concern.

Keywords: Reliability; CBSS; component; CIG; average interaction reliability, interaction ratio.

I. Introduction

The software reliability is defined as the probability that software will perform its purpose adequately for the period of time intended under the operating and environmental conditions encountered. Software reliability stresses four elements: Probability, Adequate performance, Time and Operating and environmental conditions. The purpose of the software reliability engineering is to model the failure behavior of software systems to estimate and measure the quality but traditional approach of reliability to measure the quality of complex software is not appropriate. To measure the reliability of complex software's require a new approach to measure the failure behavior of software system. Researcher & practitioner develop new method and methodology to estimate reliability of component-based software (CBS). A large number of reliability models have also been proposed to specify the problem of quantifying the system reliability, which is one of the most important attribute of quality. Therefore, the goals of this study is also to propose a methodology for CBS reliability model which mainly focus on to measure the reliability of individual component and average interaction reliability. The rest of the paper is organized as follows. The section II discusses about CBS reliability. Section III describes related work. Section IV presents theoretical understanding of the proposed methodology for reliability estimation model. Section V presents an application of the proposed model to a case study. Section VI describes the conclusion and future work.

II. Component-Based Software Reliability

Component-Based Software Development (CBSD) approach is based on the idea to develop software systems by selecting appropriate components and then to assemble them with a well-defined software architecture. Currently, Component-Based Software Engineering (CBSE) is being popular among both researchers & practitioners due to its several advantages over Object Oriented Approach. Councill and Heineman [1] define a component as a software element that conforms to a component model and can be independently deployed and composed without modification according to a composition standard. The approach of composition of component to develop component-based software is a complex process where the reliability of component is not on before integration. According to author [2], [3], larger scale use of components has raised questions on the component's reliability and the reliability of aggregate systems derived out of these components. To quantify the failure behavior of software system, software reliability is an important measure to facilitate developers to arrange sufficient test activities. There are three estimation methods to measure software reliability: *profile-based*, *state-based* and *path-based*.

Achieving a highly reliable software application is a difficult task, even when high quality, pre-tested, and trusted software components are composed together [4]. As a result, several techniques have emerged to analyze the reliability of CBS. These can be categorized as: *system-level reliability estimation* and *component-based reliability estimation* [5].

- System-level reliability estimation- Reliability is estimated for the application as a whole.
- Component-based reliability estimation- The application reliability is estimated using the reliability of the individual components and their interconnection mechanisms.

The first approach is not the most suitable for CBS because it does not consider compositional properties of systems, and does not adapt the reliability growth of individual components. Reliability prediction of CBS is getting a lot of attention with the emergence of CBSD approaches which focus on scrutinize the reliability of software application based on its components behavior and software architecture. CBS reliability can be evaluated using individual component reliability and their interconnection mechanisms.

III. Related Study

With the growing emphasis on reuse, a great deal of research effort has been done to propose a variety of reliability models and estimation techniques to assess the reliability of CBSS. *Sherif Yacoub et al.* [5], introduces a reliability model, and a reliability analysis technique for CBS. The technique is named *Scenario- Based Reliability Analysis* (SBRA). Using scenarios of component interactions, they construct a probabilistic model named Component-Dependency Graph (CDG). Based on CDG, a reliability analysis algorithm is developed to analyze the reliability of the system as a function of reliabilities of its architectural constituents. This is particularly useful when the system is built partially or fully from existing off-the-shelf components. *Gokhale et al.* [6] discuss the flexibility offered by discrete-event simulation to analyze component-based applications. Their approach relies on random generation of faults in components using a programmatic procedure which returns the inter-failure arrival time of a given component. The total number of failures is calculated for the application under simulation, and its reliability is estimated. This approach assumes the existence of a control flow graph of a program. The simulation approach assumes failure and repair rates for components, and uses them to generate failures in executing the application. It also assumes constant execution time per component interaction, and ignores failures in component interfaces and links (transition reliabilities). *Krishnamurthy et al.* [7] assess the reliability of CBS using a technique called *Component Based Reliability Estimation* (CBRE). The approach is based on test information and test cases. For each test case, the execution path is identified. The path reliability is calculated using the reliability of the components assuming a series connection (using the independent failure assumption and perfect interfaces between components). This approach does not consider component interface faults, although they are considerable factors in reliability analysis of CBS. *Goseva-Popstojanova and Trivedi* [8] present a classification of architecture-based approaches to reliability assessment of CBSS. They identify three classes based on the methods used to describe the architecture, and aggregate the failure behaviour of components and connectors. These classes are:

- a) *State-based* where software architectures and failure behaviour are represented as a Markov chain or a semi-Markov process;
- b) *Path-based* where reliability is estimated for set of execution scenarios; and
- c) *Additive models* which focus on estimating the time-dependent failure intensity of the system using components failure data.

The approach we present in this paper is a path-based approach. Our approach is based on considering interaction failures among components within a system for estimating reliability of CBSS.

IV. Proposed Interaction-Based Model

Proposed methodology for reliability estimation model is based on the following assumption:

- This study assumes that system is designed based on the concept of CBS methodology.
- This study assumes that transfer of control among components is assumed to be based on *Markov* property that means current component behavior is conditionally independent of past behavior. This assumption is not always true for systems designed at large scale because they are closely converse to *Markov* process after a long time interval [9] [10].
- All components are assumed to be independent of one another that mean every component fails independently because presence of dependence, a fault in one component could mask out faults in other component. When the fault in first component is discovered and corrected, the second component could then exhibit a higher failure rate [11].
- Probability of failure of interaction among components is assumed in advance.

The proposed methodology for reliability estimation through interaction-based model is as follows:

Step 1

Interaction-based model for reliability estimation of CBSS is a function of two important parameters i.e. *component reliability* and *average number of interaction failure*. For reliability estimation, the CBSS is used as input to create the Component Interaction Graph (CIG). The CIG is defined by the tuples $\langle N, E \rangle$ where N is a set of nodes assigned with component reliabilities and E is the set of directed edges which represents interaction between N_i and N_j . This study assumes that individual component reliability is known in advance. The node reliability is $(0 < CR_i < 1)$.

Step 2

Component's interface marks out how it interacts with another component interface. Hence, average interaction reliability of CBSS "AIR_s" is the probability that information sent among components within a system is delivered error-free. This probability includes average number of interaction failures.

Step 3

To estimate the average interaction failures "F_i" in CBSS, two factors are taken into consideration: *Interaction Ratio* and *Probability of Failure of Interaction among components*. The interaction ratio of a component "Θ" represents the ratio of total number of actual interaction over total number of available/maximum interaction possible. The value of interaction ratio lies in between 0 and 1 and is estimated as in (1).

$$\Theta_k = \frac{I(actual)}{I(max)} \quad (1)$$

The average interaction reliability "AIR_s" for CBSS is estimated as (2) with interaction ratio and probability of failure of interaction U(n).

$$AIR_s = 1 - [\sum_{n=1}^k \Theta(n) * U(n)]/N \quad (2)$$

where N is the total number of components within a system.

Step 4

The reliability "R_{CBSS}" for CBSS is estimated as (3) with components reliabilities, CR_i average interaction reliability, AIR_s.

$$R_{CBSS} = AIR_s * \prod_{i=1}^n CR(i) \quad (3)$$

In summary the prior condition for estimating the overall reliability of CBSS depends upon existence of analytical approaches, total number of components in a system and their prior information, data obtained after execution.

V. Case Study

This study assumes that all reliabilities of components are taken from the case study of given by [2] and the interaction ratio of each component assumed as per equation (1). Consider an example illustrates a component-based software system consist of 5 components. After system execution, the data contained in Table 1 is obtained. It is assumed that all five components involved in interaction.

Table 1 Example Data Set

Component	Component Reliability (CR _i)	U _n	Θ _n
C1	0.992	0.04	0.5
C2	0.989	0.02	1.0
C3	0.9988	0.001	0.5
C4	0.994	0.002	0.33
C5	0.996	0.02	1.0

As per the equation (2), average interaction reliability of a system is calculated as

$$\begin{aligned} AIR_s &= 1 - [\sum_{n=1}^k \Theta(n) * U(n)]/N \\ &= 1 - [(0.04*0.5) + (0.02*1.0) + (0.001*0.5) + (0.002*0.33) + (0.02*1.0)]/5 \\ &= 1 - [0.02 + 0.02 + 0.0005 + 0.00066 + 0.02]/5 \\ &= 1 - 0.06116/5 \\ &= 1 - 0.01223 \\ &= 0.98777 \end{aligned}$$

And using equation (3), the CBSS reliability R_{CBSS} is equal to

$$\begin{aligned} R_{CBSS} &= AIR_s * \prod_{i=1}^n CR(i) \\ &= 0.98777 * [0.992 * 0.989 * 0.9988 * 0.994 * 0.996] \\ &= 0.95827 \end{aligned}$$

VI. Conclusion

Reliability of CBSS relies not only on individual component reliability but also interaction failures are also considerable factors. So here, for this purpose, a new approach is proposed to analysis the reliability of CBSS, introduces an interaction-based model in order to measure the quality of CBS. The proposed methodology presented an approach to analyze the reliability of CBSS. The reliability estimation can be performed after system integration. The proposed methodology can be used to explore the quality measures of different system configurations. Our ongoing research involves implementing the proposed methodology on any language to estimate the CBS reliability. The other parameters like usage ratio, impact analysis of component and glue code reliability can also be considered for reliability estimation as future work.

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