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Component based Reliability Estimation using Fuzzy Inference System

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Abstract: Reliability is an important non-functional requirement for the software. To estimate the system reliability for component-based software systems (CBSSs) researchers have offered a variety of methods for doing so. Some of these methods concentrate on component reliability (which can be evaluated in design phase), while others concentrate on estimating reliability from source code. All of the approaches offered so far have been analytical. On the other hand, reliability is a real-world event that defines issues that occur in actual time. To evaluate the reliability mathematical models is not effective and efficient one. Soft computing approaches can be used to simulate real-world issues. In this paper, component reliability and transition probability is used to evaluate the CBSS reliability. By considering the above two parameters, a new fuzzy inference system model is proposed to assess the system reliability. Automatic Car Parking application is used to execute and validate the method. The fuzzification and the defuzzification method are used to calculate the system reliability. The results obtained in these methods are nearly equal. As a result, the proposed method is intended to evaluate the reliability of any application software system.

Keywords: Reliability Estimation, Fuzzification, Defuzzification, Inference Rules

1. Introduction

Now a day, Component-Based Software (CBS) is a modern technique in the field of software engineering that focuses on aggregating components into sophisticated software systems. This method has various advantages, including increased production, quality, reusability, lower maintenance costs, and marketing the products very fast. Determining reliability of the individual component and the interconnection technique among components can be used to estimate reliability. CBS reliability prediction entails quantitatively evaluating system reliability using failure forecasting methodologies. As a result, architecture-based Software Reliability Models can be used to estimate the architectural reliability of component-based systems and evaluate the behavior of their software components at various phases of development. Several architecture approach models [5,8,11] such as Gokhale model [7], Laprie model [10], Shooman model [12], Yacoub model [6], Everett model [13] etc. are used to predict the system reliability. These models are classified into the following three approaches i.e. state, path, and additive approaches. The above models use some parameters which is common such as availability, mean time to repair, reliability of component, transition probability between two components, operation profile [16], failure behavior of component, constant failure rate, number of faults, average execution time of a component and so on. In traditional reliability theory, a system's reliability is based on the probability that it will perform prescribed functions correctly (without failure) in a certain time span under predefined conditions. The failure criterion is explicitly established, and probability theory is used as the uncertainty representation scheme. But, one important difficulty is that the reliability criteria associated with conventional testing-based methodologies for certain architecture entities (for example, components and/or interfaces) are uncertain. In this context, a novel approach is presented for estimating the reliability of the software system that has the potential to eliminate the uncertainty. This is based on fuzzy sets and uses fuzzy measurements to characterize the reliability properties of software components in systems architecture. It's also been challenged whether probability applies exclusively to binary and precisely defined events under certain circumstances of uncertainty. Alternatives for dealing with these instances include fuzzy probability.[19].

Several researchers [3, 4, 17, 20, 21] proposed different techniques for estimating the component-based software reliability using fuzzy logic. CBS reliability is assessed through four instantaneous criteria (such as Component Dependency, Application Complexity, Reusability and Operational Profile) which may result in more accurate estimates [14]. Their method isn't based on a mathematical model and it does not account for the probability of component failure. Chandan Diwakar et.al.[1] have been proposed a novel model that uses series and parallel reliability models to estimate the reliability of the system and their proposed model is then tested by means of Fuzzy Logic and Particle Swarm Optimization techniques and results show that the suggested reliability model has a lower error rate in estimating CBSE reliability. For estimating CBSS reliability, a number of soft computing algorithms have been developed. These strategies are based on what has been learned in the history and show current data samples. The Modified Neuro Fuzzy Inference System, a new model for predicting CBSS reliability (MNFIS)[2] has been presented. The proposed model is applied on a variety of data sets and compares its performance with a traditional system based on fuzzy rules. Their outcomes showed better reliability.

2. Fuzzy Logic

Fuzzy logic is a type of knowledge or a mathematical technique that is used to describe concepts that aren't obvious, distinct, or precise, as well as uncertainty and information complexity. The fuzzification, Rule base, Knowledge based system and defuzzification are four stages in total for system of Fuzzy Inference.

- Fuzzification: During this process, the fuzzification module uses a membership function created with the membership function designer to transform crisp inputs into fuzzy inputs.
- Rule Base: The domain expert supplies the fuzzy if-then procedures at this step.
- Knowledge based System: The input values are handled by an inference engine based on rules provided by the domain expert during this stage (s).
- Defuzzification: At this point, the output is changed from fuzzy to crisp domain by the defuzzification module.

3. Proposed Algorithm

To estimate the system reliability using fuzzy set an algorithm is proposed. A path based approach is used to evaluate the system reliability.[15]The approach utilized to connect the design of software with the behaviour of failure is defined as path based, because the reliability of a system is determined by examining the probable execution paths of the programme, whichever empirically via testing or else algorithmically. The proposed algorithm is as follows:

Input: Reliability of component (CRe), Mean Execution Time of components (MET), and Transition Probability of Components ($Pro_{i,j}$)
Output: Estimated Reliability of components (ERe)

Compute the system reliability using a path-based strategy given by the equation below. It is determined once the architecture of a system is represented through an absorbing Discrete Time Markov Chain [22] and the each component reliability is well-known.

$$RS = \prod_{m=1}^{i} CRe_m^{\theta_m} \qquad (1)$$

RS= System Reliability, CRe_m=Component Reliabilities, m= no. of components in a given system, θ_m = expected number of a visit to the starting component (= the product of number of visits and the probability of reaching the component)

Step 1: Establish the linguistic variables that are vague.
Step 2: Choose the fuzzy membership functions to employ with the input data (Fuzzy membership function: Triangular, Quasi or Trapezoidal)

Step 3: Create fuzzy inferences using linguistic factors.
Step 4: Apply different defuzzifiction methods(centroid, max-member function, or weight average method) to acquire crisp results and determine system reliability.

4. Result Analysis and Comparison Study

An automatic car parking system [18] is considered for case study, which aim is to determine the shortest path without involving the driver. The application is made up of ten components. The proposed model employs all of the Fuzzy Inference System's GUI features to map the input data to the output data using a fuzzy-based approach.

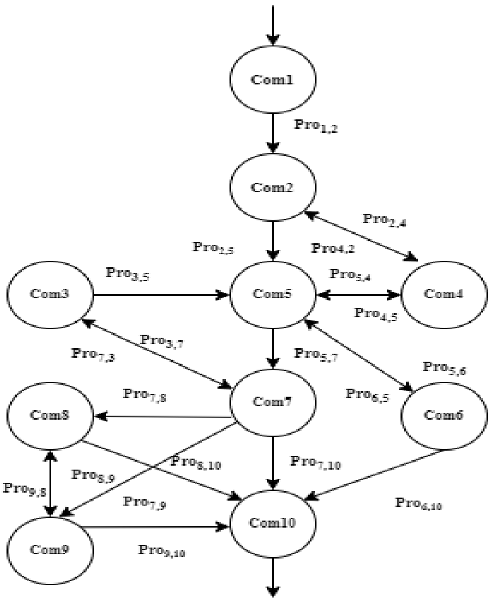

Figure 1
Component Dependency Graph for Automatic Car Parking System

Table 1 illustrates the component reliability and components mean execution time. Table 2 gives an idea about the interaction between the components.

Component#	Components Reliabilities	Mean Time Execution
Com1	0.956448	1.0
Com2	0.999765	1.62
Com3	0.9468	1.45
Com4	0.0079	1.40
Com5	0.982608	2.52
Com6	0.980764	1.26
Com7	0.949212	2.83
Com8	0.995611	1.50
Com9	0.999883	1.47
Com10	0.969578	1.00

Table1. Components reliability and mean time execution

$TR_{1,2}$ = 1.00			
$TR_{2,4}$ = 0.68	$TR_{2,5}$ = 0.32		
TR3,5 = 0.31	TR3,7 = 0.69		
TR4,2 = 0.36	TR4,5 = 0.64		
TR5,4 = 0.18	TR5,6 = 0.51	TR5,7 = 0.31	
TR6,5 = 0.43	TR6,10 = 0.57		
TR7,3 = 0.11	TR7,8 = 0.06	TR7,9 = 0.35	TR7,10 = 0.48
TR8,9 = 0.23	TR8,10 = 0.77		
TR9,8 = 0.39	TR9,10 = 0.61		

Table 2. Transition probability between two components

Component#	Mean	Variance	Expected Reliability
Com1	1	0	0.9564
Com2	0.9527	0.9180	0.9996
Com3	0.6976	0.6053	0.9635
Com4	0.9655	0.9891	0.9965
Com5	0.9011	0.7223	0.9825
Com6	0.8243	0.5918	0.9842
Com7	0.5243	0.2002	0.9733
Com8	0.6232	0.1211	0.9972
Com9	0.7130	0.1654	0.9991
Com10	1	0	0.9695

Table 3.Means, variance and expected reliability of each component from the starting component (Com1)

Table-3 describes the mean, variance and expected reliability of each components from the starting component (Com1).We compute the system reliability as 0.93 using equation (1). The Mamdani fuzzy system is being used to assess the reliability of software. The effect of number of visited component form starting component (mean) and variance of each component on overall reliability is taken into account by our fuzzy model. By considering the two parameters for the component reliability, the effect of the reliability of each component is expressed by the inference rules. In Fuzzy rules our main objective is to measure reliability. The rules are represented in Table-4 as follow:

Rules	Input		Output
	Mean	Variance	Reliability
1	Low	Low	High
2	High	Low	High
3	Medium	Medium	High
and so on			

Table 4. Rules for Determining Actual Reliability (Examples)

In the fuzzification procedure, the system reliability is 0.94. To defuzzify it, the Center of Gravity (COG) formula is applied and the result is 0.942. So, the estimated results are nearly same. In this paper, triangular membership function is used in fuzzification method. The triangular function: Let a lower limit l, an upper limit u and a middle value m, where l< m < u. Then the equation is as follows:

$$\mu_{\tilde{T}}(t) = \begin{cases} 0, l \le t \le u \\ \frac{t - l}{m - l}, l \le t \le m \\ \frac{u - t}{u - m}, m \le t \le u \end{cases} \qquad \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_(2)}$$

For defuzification method Center Of Gravity (COG) method is used. This is applied for discrete membership function. The equation is as follows:

$$t^* = \frac{\sum_{i=1}^{N} t_i * \mu(t_i)}{\sum_{i=1}^{N} \mu(t_i)} \qquad \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_(3)}$$

Where t_i = sample elements, $\mu(t_i)$ = the fuzzy membership function and N= no. of elements in the sample.

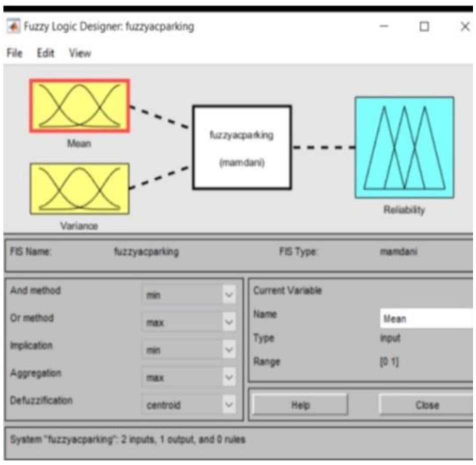

Figure 2
Fuzzy model for Reliability of the AC Parking software system

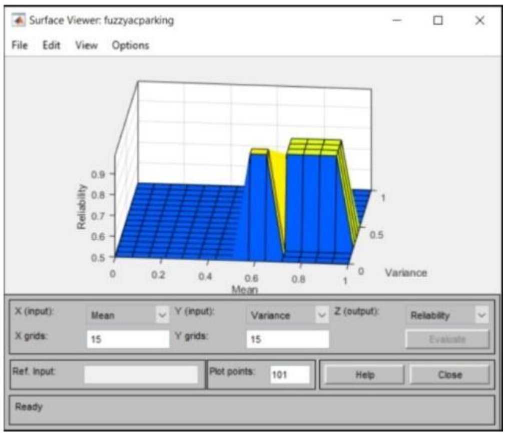

Figure 3
Surface viewer to evaluate the reliability

Comparison Study

A fuzzy-rule-based technique is being used to evaluate the reliability of a component-based software system (CBS). Although several different methods have been developed for reliability estimation, the majority of them rely on component reliability. Most research papers used program complexity, component dependency, reusability and operational profile parameters to estimate whole system reliability in real time. The Component Dependency Graph paradigm is employed in this paper. To estimate the system reliability we have to use the parameters like the expected number of visits to a component and the variance of that component. The system reliability is obtained using fuzzy logic is 0.942 which is higher than the without using fuzzy logic (0.93).

Conclusion

The study is based on a fuzzy-logic-based which helps to evaluate the component based software reliability and the component reliability leads to estimate the reliability of the overall system. Making a new product/software from scratch is difficult. It's also difficult to identify and consider parameters. A number of reliability models have been developed based on various parameters like average execution time of the components, mean time between failure etc. Soft computing is gaining traction in the area of software reliability assessment. In future work a number of soft computing techniques like artificial bee colony, genetic algorithm, particle swarm optimization technique can be implemented to estimate the system reliability.

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