Estimation of Reliability Allocation on Components Using a Dynamic Programming

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Abstract

In this paper, we used Dynamic Algorithm for the purpose of allocation of Reliability of components in a software product Design phase. The reliability and cost allocation can be used to solve the optimal allocation problems in simple systems as well as applicable to complex systems. Our experiment show near optimal solution to the problem of selecting the component and comprising the software can be obtained with lower cost. We observed different sizes of components and their reliability and cost in a structure. Finally we gave the importance of how to select reliability and cost of each component in architecture-based software.

Keywords: *software architecture, software reliability, Reliability Allocation, Reliability Estimation, Dynamic Programming*

1. Introduction

Software system is used in everywhere on our daily lives. Suppose a failure can be occurred during the operation of software can lead to economic loss and waste of time and may even cause loss of human lives also. If the unreliable software is identified in the early stage, loss may be small. Therefore unreliable software is not acceptable and it should be identified in the beginning of the software development. If it is not identified initial stage and later the defects found, the higher the cost that needs to paid for them.

Software Reliability is one of the very important and quality attributes of software since it quantifies software failures during the development process. If the higher level of Reliability of software can definitely result in more development cost. In practical Engineering , software project managers are required to estimate the cost needed to complete the development of software system is taking into account the required level of reliability is provided or not. So many software reliability models had been proposed in the past decades to help the software managers and developers to analyze and design the system. The main constraint in software development is maximizing reliability and minimizing cost.

In my previous paper estimation of reliability and cost relationship for architecture-based software paper gives the some idea about the development cost in before starting the implementation phase .

In this paper we explained design phase of each component reliability allocation in a small and large case software.

Mainly in design phase we know the main constraints. First one is system size and second one is project structure.I am taking first one is system size. System size means number of components .The components may be depends on the size of the project structure.

The argument of this paper takes the following arrangement. Section 2 introduces software reliability allocation model. Section 3 depicts how to find out the optimal allocation method by using a dynamic programming algorithm. Section 4 illustrates the application of the algorithm proposed in section 3 and section 5 offers concluding remarks and directions .

2. Software Reliability Allocation Model

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2.1 Software development cost minimization versus reliability allocation

In fact, it is impossible to develop the software reliability while dropping the software system development cost because they are two contradictory constraints. The pretended software development cost minimization can be considered from two facts of views. One is to find an optimal reliability allocation method while achieving the given reliability such that the development cost can be as small as possible; the other is how to allocate the reliability to each component on the premise of the given cost so that the system reliability can be maximized. This paper focuses on the former one.

Many systems are executed by using a set of interrelated subsystems. Reliability allocation means fixing the reliability among different subsystems so that the total system development cost (including human, material resources, development time and testing time etc) can be minimized. Reliability allocation can be used to arrangement with such kind of problem that the objective is set prior to the solution. Generally the number of the solution is more than one, as a result reliability allocation is used to deal with the optimal problem with some constraints.

3. Expending Dynamic Programming Algorithm To Solve Reliability Allocation Problem:

A software system with n components and the association function F discussed above is known. The reliability-cost coefficient α of each component and the specified system reliability target R obj is given.

The dynamic programming algorithm is as follows:

Step 1: Let S represent the reliability matrix [r1,r2, ., rn], T represent the cost matrix [c1, c2, …, cn], δ be the solving step length, Ii represent the matrix with one column and n rows in which only the value of the ith element is 1 and the rest are all 0. Assume S0=[maxr, maxr, …, maxr], maxr represents the maximized possible reliability, for example 0.9999, which means the initial reliability values of the components are all maxr.

Step 2: As for S0, T0 and , C0 can be given by and system reliability R0 can be given by function F.

Step 3: If R0<Robj then stop and return. No solutions.

Step 4: Set Rate=0;

Step 5: for i=1 to n
- i) S’=S0 - Ii*δ;
- ii) With regard to S’, Generate reliability R’ with the function F, T’ with (7), total cost C’
- iii) ΔC= C0 - C’; ΔR= R0 – R’;
- iv) if R’ ≥ Robj and ΔC/ΔR >Rate then Set Rate=ΔC/ΔR , R=R’ , S=S’ , C=C’ , T=T’;

Step 6: if R0≠R then set S0=S; R0=R; C0=C; T0=T; return to step 4

Where reliability allocation result S0 is the reliability of each component. R0 and C0 are the corresponding system reliability and expected system development cost. T0 is the expected development cost allocated to each component. Notice from the above that prerequisite to the correctness of the algorithm is that the decrease in reliability of one component can result in that of the whole system and lower the development cost. But that can be guaranteed in our algorithm. The aim of step 5 iv) in the above algorithm is to select an optimal component whose decrease in reliability can result in the maximal cost/reliability variation, which makes the single step programming optimized so that optimal reliability allocation of the ultimate system is guaranteed.

4. Example and Result

Here we choose a system with four independent components r1, r2, r3, r4. We assume that all the components are essential to the system and their failures are statistically independent. Therefore, the relationship between the total system reliability r and its components’ reliability ri (i=1, 2, 3,4) can be stated as: r = F (r1, r2, r3,r4) = r1*r2*r3*r4 Suppose that the complexities of the components are 0.35, 0.52,0.74 and 0.91 respectively. In order to minimize the system development cost and the system reliability shall be no less than 0.94, how to allocate the reliability to each component. Set the precision of computing is 0.01.

Such a problem can be rewritten as:

R＝r1*r2*r3*r4≤0.94
c1= - 0.35/ln r1
c2= - 0.52/ln r2
c3= - 0.74/ln r3
c4= - 0.91/ln r4

Compute the values of parameters (r1, r2, r3, r4) with which the total cost C (C ＝ c1+c2+c3+c4) is minimized. With respect to each component, we compute the cost with the reliability from 0.91 to 0.99 (increment is 0.01) according to the reliability/cost function model in the data set as shown in Table 1.

According to the algorithm above, set initial state S0 = [0.99, 0.99, 0.99, 0.99]. Accordingly, T0 = [34.82, 51.74, 73.63, 90.54], δ=0.01, and the system cost C0= 34.82+51.74+73.63+90.54 = 250.73, system reliability R0= 0.99 * 0.99*0.99*99＝0.96.

Set i=1, 2, 3, 4 then compute separately with different value:

1) S’= S0 – [0.01, 0, 0, 0] = [0.98, 0.99, 0.99, 0.99],

R'=0.95, T'= [17.32, 51.74, 73.63, 90.54], C'=233.23 ΔC= 17.5, ΔR=0.01, ΔC/ΔR=1750

2) S'= S0 – [0, 0.01, 0, 0] = [0.99, 0.98, 0.99, 0.99], R'=0.95, T'= [34.82, 25.74, 73.63, 90.54], C'=224.73 ΔC=26, ΔR=0.01, ΔC/ΔR=2600

3) S'= S0 – [0, 0, 0.01, 0] = [0.99, 0.99, 0.98, 0.99], R'=0.95, T'= [34.82, 51.74, 36.63, 90.54], C'=213.73 ΔC= 37; ΔR=0.01, ΔC/ΔR=3700

4) S'= S0 – [0, 0, 0, 0.01] = [0.99, 0.99, 0.99, 0.98], R'=0.95, T'= [34.82, 51.74, 73.63, 45.04], C'=205.23 ΔC= 45.5; ΔR=0.01, ΔC/ΔR=4550

Choose the optimal result 2), set S0 = [0.99, 0.98, 0.99, 0.99],continue to perform the same operation：

1) S'= S0 – [0.01, 0, 0, 0] = [0.98, 0.98, 0.99, 0.99], R'=0.94, T'= [17.32, 25.74, 73.63, 90.54], C'=207.23, ΔC=43.5, ΔR=0.01, ΔC/ΔR=4350

2) S'= S0 – [0, 0.01, 0, 0] = [0.99, 0.97, 0.99, 0.99], R'=0.94, T'= [34.82, 17.10, 73.63, 90.54], C'=216.09 ΔC=34.64, ΔR=0.01, ΔC/ΔR=3464

3) S'= S0 – [0, 0, 0.01, 0] = [0.99, 0.98, 0.98, 0.99], R'=0.94, T'= [34.82, 25.74, 36.63, 90.54], C'=187.73 ΔC=63; ΔR=0.01, ΔC/ΔR=6300

4) S'= S0 – [0, 0, 0, 0.01] = [0.99, 0.98, 0.99, 0.98], R'=0.94, T'= [34.82, 25.74, 73.63, 45.04], C'=179.23 ΔC=71.5; ΔR=0.01, ΔC/ΔR=7150

Choose the optimal result 3), set S0 = [0.99, 0.99, 0.98, 0.99], continue to perform the same operation：

1) S'= S0 – [0.01, 0, 0, 0] = [0.98, 0.99, 0.98, 0.99], R'=0.94, T'= [17.32, 51.74, 36.63, 90.54], C'=196.23, ΔC=54.5, ΔR=0.01, ΔC/ΔR=5450

2) S'= S0 – [0, 0.01, 0, 0] = [0.99, 0.98, 0.98, 0.99], R'=0.94, T'= [34.82, 25.74, 36.63, 90.54], C'=187.73 ΔC=63, ΔR=0.01, ΔC/ΔR=6300

3) S'= S0 – [0, 0, 0.01, 0] = [0.99, 0.99, 0.97, 0.99], R'=0.94, T'= [34.82, 51.74, 24.30, 90.54], C'=201.4 ΔC=49.33; ΔR=0.01, ΔC/ΔR=4933

4) S'= S0 – [0, 0, 0, 0.01] = [0.99, 0.99, 0.98, 0.98], R'=0.94, T'= [34.82, 51.74, 36.63, 45.04], C'=168.23 ΔC=82.5; ΔR=0.01, ΔC/ΔR=8250

Choose the optimal result 4), set S0 = [0.99, 0.99, 0.99, 0.98],continue to perform the same operation：

1) S'= S0 – [0.01, 0, 0, 0] = [0.98, 0.99, 0.99, 0.98], R'=0.94, T'= [17.32, 51.74, 73.63, 45.04], C'=187.73, ΔC=63, ΔR=0.01, ΔC/ΔR=6300

2) S'= S0 – [0, 0.01, 0, 0] = [0.99, 0.98, 0.99, 0.98], R'=0.94, T'= [34.82, 25.74, 73.63, 45.04], C'=179.23 ΔC=71.5, ΔR=0.01, ΔC/ΔR=7150

3) S'= S0 – [0, 0, 0.01, 0] = [0.99, 0.99, 0.98, 0.98], R'=0.94, T'= [34.82, 51.74, 36.63, 45.04], C'=168.23 ΔC=82.5; ΔR=0.01, ΔC/ΔR=8250

4) S'= S0 – [0, 0, 0, 0.01] = [0.99, 0.99, 0.99, 0.97], R'=0.94, T'= [34.82, 51.74, 73.63, 29.88], C'=190.07 ΔC=60.66; ΔR=0.01, ΔC/ΔR=6066

all of the results R' are less than the specified reliability target 0.94. Therefore, the reliability allocation in this case is as below:

1) System reliability allocation S0= [0.99, 0.99, 0.98, 0.98];

2) System reliability R0=0.94;

3) Expected system development cost C0 = 168.23;

4) Expected development cost assigned to each components T0 = [34.82, 51.74, 36.63, 45.04].

5.Conclusion

Software reliability allocation for SDLC shows an important role during software product design phase and implementation phase which has close relationship with software modeling and cost evaluation. We formulated an architecture-based approach for modeling software reliability optimization problem, on this basis a dynamic programming algorithm has been proven in this paper which can be used to allocate the reliability to each component so as to minimize the cost of designing software while meeting the desired reliability objective. The result of our experiment show an optimal or approximate optimal solution to the problem of selecting the various sizes of components comprising software can be obtained with lower cost (a high reliability). The reliability and cost allocation model presented in this paper can be used to solve the optimal allocation problems in simple systems; it is also relevant in complex systems

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s.no	r1	c1	r2	c2	r3	c3	r4	c4
1	0.91	3.71	0.91	5.51	0.91	7.84	0.91	9.65
2	0.92	4.20	0.92	6.24	0.92	8.88	0.92	10.91
3	0.93	4.82	0.93	7.16	0.93	10.20	0.93	12.54
4	0.94	5.66	0.94	8.40	0.94	11.96	0.94	14.71
5	0.95	6.82	0.95	10.14	0.95	14.43	0.95	17.74
6	0.96	8.57	0.96	12.74	0.96	18.13	0.96	22.29
7	0.97	11.49	0.97	17.10	0.97	24.30	0.97	29.88
8	0.98	17.32	0.98	25.74	0.98	36.63	0.98	45.04
9	0.99	34.82	0.99	51.74	0.99	73.63	0.99	90.54

TABLE 1: COST AND RELIABILITY DATA SET

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