Development of RBDGG Solver and Its Application to System Reliability Analysis

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1. Introduction

For the purpose of making system reliability analysis easier and more intuitive, RBDGG (Reliability Block diagram with General Gates) methodology [1] was introduced as an extension of the conventional reliability block diagram. The advantage of the RBDGG methodology is that the structure of a RBDGG model is very similar to the actual structure of the analyzed system, and therefore the modeling of a system for system reliability and unavailability analysis becomes very intuitive and easy. The main idea of the development of the RBDGG methodology is similar with that of the development of the RGGG (Reliability Graph with General Gates) methodology [2], which is an extension of a conventional reliability graph.

The newly proposed methodology is now implemented into a software tool, RBDGG Solver. RBDGG Solver was developed as a WIN32 console application. RBDGG Solver receives information on the failure modes and failure probabilities of each component in the system, along with the connection structure and connection logics among the components in the system. Based on the received information, RBDGG Solver automatically generates a system reliability analysis model for the system, and then provides the analysis results.

In this paper, application of RBDGG Solver to the reliability analysis of an example system, and verification of the calculation results are provided for the purpose of demonstrating how RBDGG Solver is used for system reliability analysis.

2. Application to an Example System

The example system used in this paper is the bridge structure system shown in Fig. 1, which is also used in Kim [3].

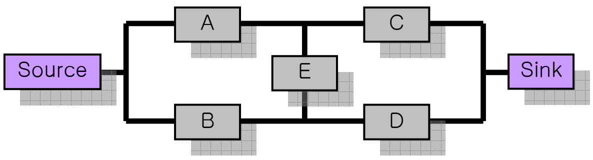

Fig.1. Bridge structure system

The single failure probabilities of components in the example system are given in Table I. For comparison purpose, the same data used in Kim [3] is reused in this paper.

Table I: Single failures in the example system

Failure modes	Failure probability
SingleFailure_A	0.01
SingleFailure_B	0.02
SingleFailure_C	0.13
SingleFailure_D	0.23
SingleFailure_E	0.21

In this paper, not only the single component failures but also common cause failures (CCFs) of two components in the system are considered. Table II shows the two CCFs and their failure probabilities considered in this paper.

Table II: CCFs in the example system

Failure modes	Failure probability
CCF_AB	0.0005
CCF_CD	0.065

To analyze the reliability of the example system using RBDGG Solver, it is necessary to input necessary information related to the example system into RBDGG Solver. For this purpose, the first step is to define a node corresponding to a component in the example system. After defining the node, the information related to the failure modes of the component and corresponding failure probabilities needs to be provided. For example, component A in Fig. 1 is represented as a node and the information related to the failure modes and failure probabilities corresponding to the component A is attached to the node for the components A as shown in Fig. 3.

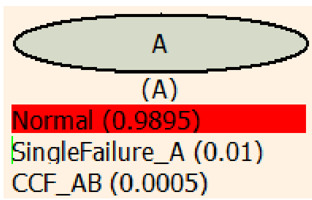

Fig.3. A node representing component A with a failure mode and failure probability information for the component A

After defining the nodes corresponding to the components in the system and providing the related failure mode and failure probability information, the next step is to connect the defined nodes so that the physical and logical structures of the system can be reflected. Fig. 4 shows the connection of the defined nodes for the reliability analysis of the example system with RBDGG Solver. As can be seen in Fig. 4, the system structure in the RBDGG model is very similar with the actual structure of the example system shown in Fig. 1, which is one of the most important advantages of using the RBDGG methodology.

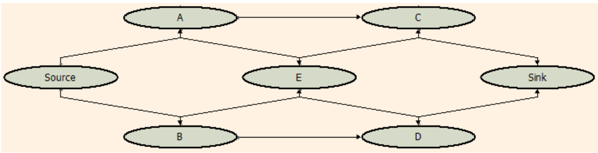

Fig. 4. System structure information for the bridge structure system given to RBDGG Solver

Based on the provided information mentioned above, RBDGG Solver is able to generate a system reliability analysis model for the example system and provide the analysis results. The system unavailability calculated by RBDGG Solver is 0.0377024.

3. Verification with Fault Tree Analysis

To verify the calculation results from RBDGG Solver for the example system, a fault tree analysis is also performed. Fig. 5 shows the fault tree developed for the verification purposes. The fault tree analysis is performed using AIMS-PSA [4], and the quantification is performed using FTBDD, which is a fault tree solver using a binary decision diagram (BDD) algorithm. The system unavailability calculated using the fault tree analysis is 0.03770244, which is the same value from RBDGG Solver.

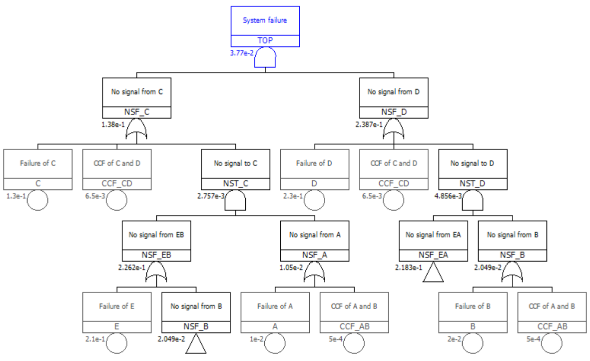

Fig. 5. Fault tree for the example system

Not only the system unavailability, but also other probabilities inside the bridge structure system, are compared. Table III shows the output failure probabilities of the components in the bridge structure system. For example, the probability that C fails to provide correct output can be found in the output of the RBDGG Solver, which is 0.138038. The same probability can also be found in NSF_C gate of the fault tree model shown in Fig. 5, which is 0.1380379. From Table III, it can be found that the output failure probabilities calculated with RBDGG Solver and the fault tree analysis are the same, and therefore it can be concluded that the analysis results using RBDGG Solver for the example system are verified.

Table III: Comparison of quantification results

	RBDGG Solver	Fault Tree
A	0.010495	0.010495
B	0.02049	0.02049
C	0.138038	0.1380379
D	0.23872	0.2387197
System	0.0377024	0.03770244

4. Summary and Conclusion

In this paper, the use of RBDGG Solver for system reliability analysis is demonstrated, with application to an example system. Based on the failure mode and failure probability information of each component in the system, and the structural connection information of the system, RBDGG Solver automatically generates a system reliability analysis model and the analysis results, without manually developing system reliability analysis models such as a fault tree model. The analysis results by RBDGG Solver are compared to the analysis results by a fault tree analysis, and it is shown that the two results are the same.

The development of RBDGG Solver is expected to facilitate the application of the RBDGG methodology, which is a newly developed methodology for system reliability analysis.

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