

# An Intuitive and Practical Method for Reliability Analysis of Complex Systems

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## I. INTRODUCTION

System reliability analysis refers to the evaluation of the reliability of a system based on the reliabilities of its elements. Several methods can be applied to the system reliability analysis, such as reliability graph, fault tree analysis, Markov chain, and Monte Carlo simulation. Each method has its own characteristics, merits and demerits. Among the existing methods, the fault tree analysis is most widely used due to its expression power, applicability to complex systems and various tool supports. But, drawing a fault tree is a cumbersome task even for the experts who is familiar to it, and requires a great amount of attention and caution to represent a system correctly. This is mainly because the fault tree analysis is not an intuitive

method. A fault tree has to be drawn based on the structure of a system and the reliabilities of the system's elements. Because drawing and verifying fault trees are the tasks that human analysts have to perform, there are always possibilities of human errors. In order to reduce necessary works for the analysis and verification, and the possibilities of human errors, we believe that an intuitive method for system reliability analysis should be developed.

## II. RELIABILITY GRAPH WITH GENERAL GATES

Reliability graph is particularly attractive for system reliability analysis due to its intuitiveness. Sometimes, it is possible to make a one-to-one match from the actual structure of a system to the reliability graph for

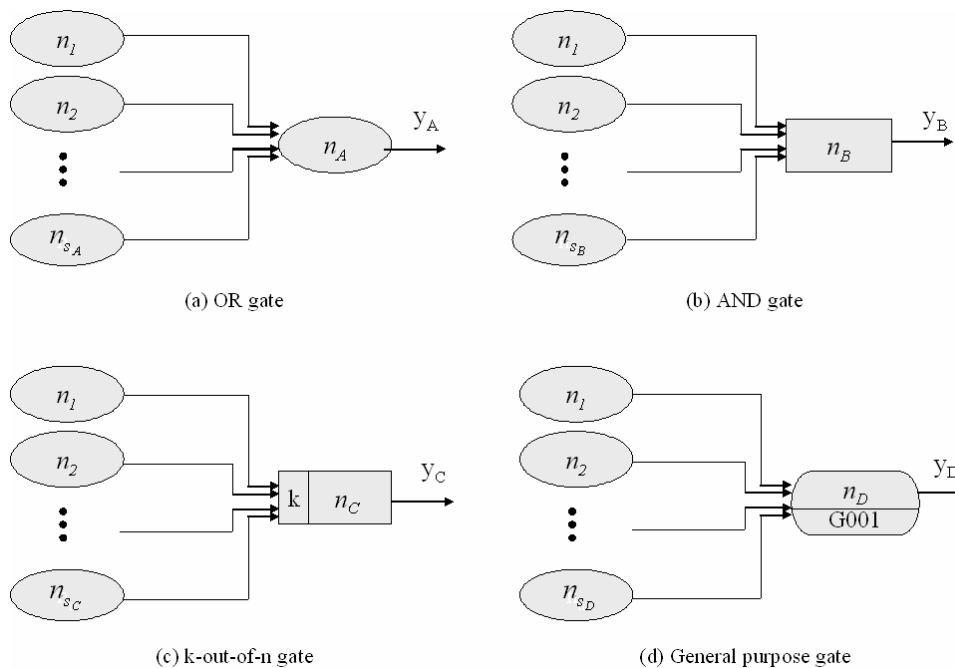


Fig. 1. Four different kinds of nodes for Reliability Graph with General Gates

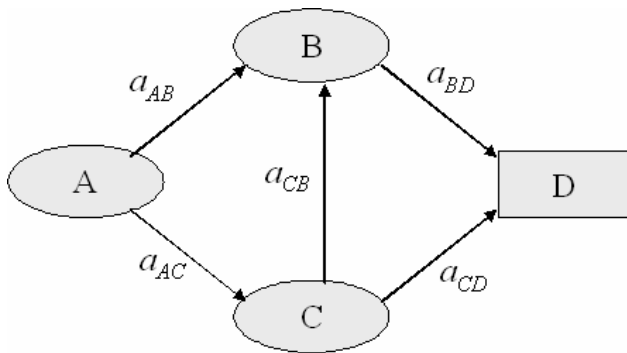


Fig. 2. Reliability graph with general gates model for an example system

the system. But, the most serious shortcoming is its limitation in expression power. We found that the limitation comes from the fact that reliability graphs use only OR gate.

To overcome the limited expression power, we propose a new method, named reliability graph with general gates, which utilizes general gates, instead of only OR gate. Based on our experience on fault tree analysis, we defined graphical notations for the three most frequently used gates, OR gate, AND gate and k-out-of-n gate.

Sometimes, the use of only existing gates is not sufficient to describe the structure of a system correctly and intuitively, especially when describing complex relationships. Therefore, we also define a graphical notation for general purpose node. The general purpose node indicates that a special truth table for the node is available. Instead of using the combination of OR nodes, AND nodes and others, reliability graph uses only one node (the general purpose node) to preserve its intuitiveness, by making one-to-one match to an actual component in a system. Fig. 1 shows the graphical notations for the four different kinds of nodes. Reliability graph with general gates can be drawn using the four different kinds of nodes shown in Fig. 1.

For the calculation of reliability graph with general gates, we also propose a calculation method, which is the transformation of a reliability graph with general gates to an equivalent Bayesian network. The probability tables for OR gate, AND gate, and k-out-n-gate gate can be determined using equation shown in [1].

### III. AN ILLUSTRATIVE EXAMPLE

Fig. 2 shows the reliability graph with general gate

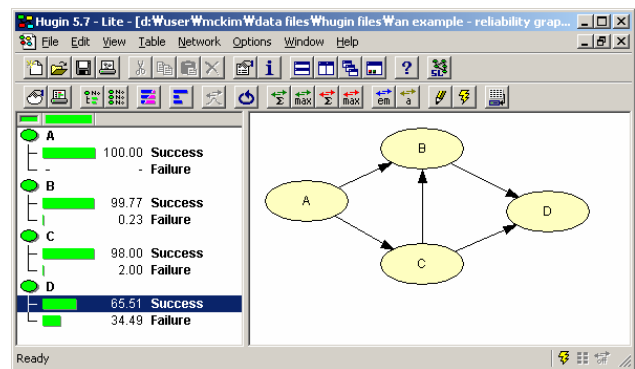


Fig. 3. Reliability analysis result for the example system

model for an example system. The example system is a data delivery system from node A (source node) to node D (target or destination node) under random failures of five transmission lines,  $a_{AB}$ ,  $a_{AC}$ ,  $a_{CB}$ ,  $a_{BD}$ ,  $a_{CD}$ . As shown in Fig. 2, node D is a node with AND gate and therefore requires the outputs from both node B and node C. The probability tables for the equivalent Bayesian network are determined based on the (1) and (2). We assume the reliabilities of  $a_{AB}$ ,  $a_{AC}$ ,  $a_{CB}$ ,  $a_{BD}$ , and  $a_{CD}$  to be 0.99, 0.98, 0.79, 0.87, and 0.77, respectively. Figure 3 shows the evaluation result using a commercial software tool for Bayesian networks, named Hugin™.

Based on Fig. 3, the reliability of the example system is determined to be 0.6551. To verify the result, we also performed fault tree analysis for the example system and we could get the same result.

### IV. CONCLUSIONS

The proposed method is an intuitive and easy-to-use method while as powerful as fault tree analysis. The proposed method is also very practical in that various commercial or free software tools for Bayesian networks such as Hugin™ and MSBNx™, which supports the proposed method, are already available on the internet as sharewares.

### REFERENCES

- [1] Man Cheol Kim and Poong Hyun Seong, "Reliability Graph with General Gates: An Intuitive and Practical Method for System Reliability Analysis, Reliability Analysis and System Safety, To be published