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主　論　文　の　要　旨

論文題目　System Reliability Bounds Analysis Using Linear Programming and Its Application (線形計画法を用いたシステム信頼性の上下限解析法とその適用に関する研究)

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論　文　内　容　の　要　旨

In general, a system consists of a number of interrelated and interdependent components. Also, a system with a set of components can be considered as a component in a larger system. There could be many different types of systems such as a cell, a bridge, a galaxy. Engineering systems considered in this research have two important states, i.e., functional state and failure state, and the probability that a system is in its functional state (design purpose) during a specified period of time is the reliability of the systems. The failure probability of a system is the complement of the reliability of the system.

Estimation of the failure probability of a system usually is very difficult and time consuming especially when there exists a dependency among the component states and when the number of components is large. Researchers are trying to find the upper and lower bounds on the exact failure probability of the system. Among those methods, Song and Der Kiureghian proposed the linear programming (LP) bounds method for computing the bounds on the failure probability of general systems based on the information of the joint failure probabilities of *k* components.

The LP bounds method has a number of advantages such as providing the narrowest possible result of bounds on the system failure probability for any level of information and having a wide applicability for many systems. There exists, however, a critical drawback in the LP bounds method. The size of the LP problem, which is usually related to the number of design variables and the number of constraints, increases exponentially with the number of components. This size issue related to computation burdens would be a hindrance if one wants to apply the LP bounds method to a large system. The LP bounds method can handle a system with only 18 components using a state-of-the-art personal workstation.

The challenges of the computation burdens in the system reliability analysis motivated this Ph.D. research, and the goal of this research is to propose new system reliability analysis methods that can estimate the reliability of a large system efficiently and accurately. Based on the LP bounds method, this research first proposes the relaxed linear programming (RLP) bounds method to overcome the size issue of the LP problem for a pure series system and a pure parallel system. A conceptually simplified universal generating function (UGF) of the system is proposed in the RLP bounds method, and the states of the system is encoded in the z transform employed in the UGF. The probabilities corresponding to the states encoded in the z transform serve as the design variables of linear programming. Like the LP bounds method, the RLP bounds method is based on the information of the joint failure probabilities of k components. The constraints in the LP bounds method are based on the joint failure probabilities of the k components directly, however, the constraints in the RLP bounds method are based on the relaxed bounds on the joint failure probabilities of the k components.

The most important contribution of the RLP bounds method is that the size of LP problem can be reduced dramatically; e.g., the number of design variables can be decreased from 2^n to $n^2 - n + 2$. As a result, the limitation of the number of components in the RLP bounds method using a personal workstation increase to 512. Still, the RLP bounds method can provide the result comparable to that of the LP bounds method. The main drawback of the RLP bounds method is that it is only applicable to a pure series system as well as a pure parallel system. In order to extend the applicability of the RLP bounds method, the extended RLP bounds method based on failure modes is introduced. The entire system can be decomposed into subsystems based on the failure modes. The bounds on the failure probability of each subsystem can be estimated by the RLP bounds method, and these bounds are then used as constraints in solving the LP problem in order to estimate the failure probability of the entire system. As a result, the bounds on the failure probability of a general system with a large number of components can be estimated accurately and efficiently.