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OPTIMUM ALLOCATION OF REDUNDANT COMPONENTS FOR RELIABILITY MAXIMIZATION

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1. INTRODUCTION

Redundancy allocation for Reliability maximization is a pressing problem and many researchers came out with many solutions to this problem under different types of coherent structure. However, under real life distributional framework solutions to this optimization problem become analytically hard. As a result, heuristic algorithms have crept into this field to provide with near optimum solutions as may be seen from the literature. Thus, development of the subject depends on distributional and structural assumption and on optimum and heuristic solutions. These have made the problem wide open and call for a unified approach.

Earlier Works

Attempts to solve the problem of redundancy allocation and reliability maximization started in 1950s. Optimal redundancy of a complex system was addressed by Black and Proschan in 1959. After that, Nakagawa and Nakashima (1977) tried to heuristically find out the method for determining optimum reliability allocation of n-stage series system. Tillman et al. (1977) worked on component reliability and redundancy for arriving at optimum system reliability. In 1978, Nakagawa et al. allocated reliability optimally by branch-and-bound technique. Bulfin and Liu (1985) used a maxi-min approach to allocate redundancy for series-parallel systems. Their work focused on obtaining the optimal allocation of components so that the least reliable subsystem is as reliable as possible. Next Optimal Allocation of Components in Parallel-Series and Series-Parallel Systems was addressed by Neweihi et al.(1986). Boland et al.(1988) introduced a new measure of component importance, called redundancy importance, in coherent systems. This helped in active redundancy allocation in coherent systems. The component redundancy allocation for maximizing reliability of a boiler feed-water treatment plant has been analyzed by Khadke (1989) where the main constraint is the cost of the redundancy components. Revyakov (1993) allocated components for a distributed system for reliability maximization.

A bound heuristic algorithm for solving reliability redundancy optimization was proposed by Jianping (1996). Rao et al. (1999) addressed the optimal allocation of reliability among components that are to be assembled into a system. Coit(2001) described Cold-standby redundancy optimization for nonrepairable systems and in the same year Prasad et al. introduced the idea of maximization of a percentile life of a series system through component redundancy allocation. Lyu et al.(2002) optimally allocated test resources for software reliability growth modeling in software development.

Lin and Kuo (2002) worked on reliability importance and invariant optimal allocation. Coit(2003) choose redundancy strategies for maximization of system reliability.

In the recent past, Henin(2006) worked on Optimal allocation of unreliable components for maximizing expected profit over time. Thereafter in 2007, Liang et al. used Variable neighbourhood search for redundancy allocation problems. Pandey et al. (2007) studied a multi-objective reliability application. Mori et al. (2007) developed a hybrid algorithm based on simulated annealing and genetic algorithm to reliability redundancy optimization. Saha and Dhillon (2007) presented stochastic models representing redundant three-state device systems with critical human errors and common-cause failures. Bhattacharya and Samaniego (2008) addressed the problem of identifying optimal allocation(s) of independent components with varying individual reliabilities to specific locations within a given coherent system. Coelho (2009) designed Reliability–redundancy optimization by means of a chaotic differential evolution approach. In 2010, Coelho et al. used a Chaotic Differential Harmony Search Algorithm for redundancy optimization. Wang wt al. (2010) introduced maulti-objective approaches to optimal testing resource allocation in modular software systems. Defence and attack of systems with variable attacker system structure detection probability was stydied by Levitin and Hausken (2010). Then Sahoo et al.(2010) used a genetic algorithm based reliability redundancy optimization when reliability values are in interval domain.

Soylu and Ulusoy (2011) preferred ordered classification for a multi-objective max–min redundancy allocation problem and Mahapatra and Mahapatra (2011) used Intuitionistic Fuzzy Multi-Objective Programming for Redundancy Optimization.

Thus, it may be noted that there is a two-fold attack for reliability optimization. Operations Research techniques have made in road into the literature, which was earlier dominated by heuristic algorithms like Equal Apportionment technique, the ARINC Apportionment technique, the AGREE Allocation method and Effort Minimization algorithm for reliability apportionment.

Research Gap

Many of these solutions are problem dependent and need to be generalized for addressing a general problem. In fact some of them are distribution dependent too and can not be used under a variation in the stochastic description of the components. Our aim is to address these gaps and try for an unification and generalization of these approaches to translate the overall system performance, including reliability, into component performance in terms of component reliability. The process of assigning reliability requirements to individual components to attain the specified system reliability will be referred as reliability allocation. This allocation of strengths to components is very complex in nature. A component may play a crucial role for the functioning of the system. In particular, the method of accomplishing this function, the complexity of the component, and the reliability of the component changing with the type of function to be performed are to be addressed in details.

Objective of the Study

To be more specific our objectives are

1. Address fundamental coherent structures for reliability optimization where cost constraints are non operative.
2. Address fundamental coherent structures for reliability optimization where cost constraints are operative.
3. Consider alternative agenda for optimization based on management principles to strike a balance between value and cost.
4. Make an attempt to arrive at decision rule based solutions under life distributional class properties.

Proposed Methodology

Allocation of specified system reliability R_S to the component reliability requires solving the following inequality

$$f(R_1, R_2, \dots, R_n) \geq R_S$$

where

R_i is the reliability allocated to i^{th} unit

f is functional relationship between the components and the system.

Tools to be used for that purpose are

1. Optimization techniques reported so far in Operation Research like non-linear programming, dynamic programming, geometric programming etc.
2. Any new technique to be developed by the researcher to suit the general purpose.
3. Statistical treatment to describe the stochastic behavior of the component lives like describing the component lives in terms of normal, Weibull and exponentional distribution.
4. Redundant components allocation with the help of numerical method.

Relevance of the Study

This study will enrich us with the ideas of

1. Economy in manufacturing time and better production control.

2. Better product design, manufacturing methods and testing procedure, which will lead to customer satisfaction.

3. Fulfillment of mission leading to scientific achievement.

4. Development of the relationship between component, subsystem and system reliabilities.

5. Understanding of the basic reliability problems inherent in the system design.

6. Understanding of software reliability for better software design.

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