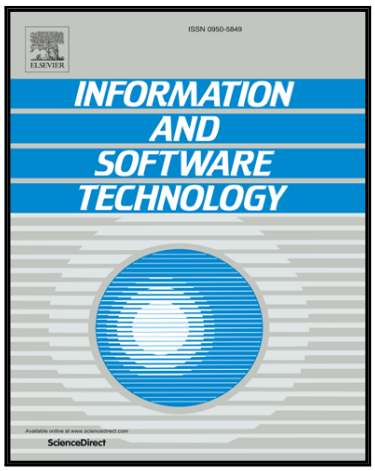

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Xiang Qiu , Shaukat Ali , Tao Yue , Li Zhang

PII: S0950-5849(16)30190-2
DOI: 10.1016/j.infsof.2016.09.010
Reference: INFSOF 5768

To appear in: *Information and Software Technology*

Received date: 27 March 2015
Revised date: 26 September 2016
Accepted date: 28 September 2016

Please cite this article as: Xiang Qiu , Shaukat Ali , Tao Yue , Li Zhang , Reliability-Redundancy-Location Allocation with Maximum Reliability and Minimum Cost Using Search Techniques, *Information and Software Technology* (2016), doi: 10.1016/j.infsof.2016.09.010

Reliability-Redundancy-Location Allocation with Maximum Reliability and Minimum Cost Using Search Techniques

Xiang Qiu[a,d], Shaukat Ali[b], Tao Yue[b,c] and Li Zhang[d,*]
[a] China Mobile Group Design Institute Co., Ltd., Beijing, China
[b]Simula Research Laboratory, Oslo, Norway
[c]Department of Informatics, University of Oslo, Oslo, Norway
[d]School of Computer Science and Engineering, Beihang University, Beijing, China
[*]Corresponding author: E-mail: lily@buaa.edu.cn
qiuxiang008@gmail.com, {shaukat, tao}@simula.no, lily@buaa.edu.cn

Abstract

Context: A safety critical system requires an automated and optimal allocation of redundant component instances to its existing components, including: 1) the selection of components (locations) on which the redundancy must be applied, 2) how many redundant component instances of varying reliability and cost should be allocated to each selected location.

Objective: Our work aims to searching for the near optimal allocation solutions achieving the higher reliability of the system within the allowed cost. Such allocation must be made earlier, for example, while designing the architecture of the system to avoid unnecessary complexity of addressing unsafe situations discovered in the system development and deployment phases.

Method: With the above objective in mind, we propose a search-based allocation approach based on the overall objectives of maximizing the overall system reliability and minimizing the cost of introducing and allocating redundancy structures to the system. The architecture of a system modeled using the Unified Modeling Language (UML) along with redundancy structures is encoded as an optimization problem. To guide a search algorithm to solve the problem, we propose a fitness function based on the two optimization objectives: high reliability and low cost.

Results: We empirically evaluated the performance of four search algorithms (Genetic Algorithm, (1+1) Evolutionary Algorithm, Alternating Variable Method (AVM) and Random Search) together with the proposed fitness function on 10 real-world Subsea Oil&Gas Production Systems of varying complexity. Results show that the AVM algorithm significantly outperforms the rest.

Conclusion: Based on the results of empirical evaluation, we found that AVM can provide the best allocation of redundancy structures as compared to the rest of the algorithms. On average, AVM provided 0.008% of more reliability while saving 26.78% on allocation cost as compared to RS. Our novel solution based on the results of empirical evaluation is implemented as a software tool.

***Keywords**:* Reliability Block Diagram; Redundancy Structure; Search Algorithms; UML; Optimization; Empirical Studies.

1 Introduction

One of common ways of improving the reliability of a safety critical system is by introducing redundancy to the system. When applying redundancy to a system, two questions have to be answered: 1) *how* many redundant component instances should be allocated for a set of specified system components (redundancy locations); 2) *what* type of candidate components should be assigned for redundancy locations [1]. The first question is classified as the Redundancy Allocation Problem (RAP) in the literature, whereas the above two questions are classified as Reliability-Redundancy-Allocation Problem (RRAP) [1]. Both of these problems are optimization problems aiming for finding a near optimal redundancy allocation for a system with the