Environmental-friendly reliability allocation for product platform based on expert measurement and ICN

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Abstract

Traditional methods can not satisfy the reliability allocation demands for modern products. Firstly, they couldn’t guarantee the efficient access and constant exchange of large amounts of expert measurement information on reliability allocation. Secondly, they don’t take environmental attributes into consideration which deserve more attention for the increasingly serious carbon emissions and energy crisis. Thirdly, they are not appropriate for product platforms which are replacing rapidly individual products. To solve these problems, an integrated reliability allocation method for product platform based on expert measurement and Information-Centric Networking (ICN) is proposed in this paper, in which vast quantities of expert measurement data is managed through ICN. Besides, environmental attributes of product platform, dynamic market changes, and module types are considered by the integration of maximal entropy ordered weighted averaging (ME-OWA) and analytical hierarchical process (AHP). The validity of this method is demonstrated by a numerical example.

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1. Introduction

In engineering issues, reliability allocation tends to be utilized to guarantee the ability of product or system to conduct its required function within a specified period mission time, in which the study, evaluation, and life-cycle management of reliability etc. are included. The purpose of reliability allocation is to determine the reliability of each constituent subsystem and component to guarantee the reasonable reliability of the targeted system [1]. It is an important and iterative task related to the quality of products in the design of all engineering system which should be performed reasonably in the design cycle to guide later detailed design of products [2].

The problem of reliability allocation has been widely discussed by many scholars, and various reliability allocation methods have been developed during the past few decades. Given the relationship between product cost and its reliability, Salazar [3] proposed a method which constantly focuses on the minimization of system cost in the process of reliability allocation.
Variables

\[ w_i \] Weight of the \( i \)th attributes
\[ I \] Number of attributes
\[ \alpha \] Conditional parameter
\[ G_{ij} \] Expert evaluation about the pairwise comparison between the \( i \)th module and the \( j \)th module for the \( k \)th influence factor.
\[ n \] Number of modules of the whole system
\[ S_k \] Total scores of every module in the \( k \)th influence factor \( S_k \)
\[ W_C \] Weighed vector of influence factor
\[ B_{ij} \] Importance of the \( i \)th module regarding the \( j \)th module for the \( k \)th influence factor
\[ B_k \] Element's judgment matrix of alternative layer relative to the \( k \)th influence factor
\[ Cl \] Consistency degree of the matrix \( B_k \)
\[ \Delta B_k \] Largest eigenvalue of the matrix \( B_k \)
\[ W_{BK} \] Weighed vector obtained by the matrix \( B_k \)
\[ w_{BKj} \] Weight of the \( i \)th module relative to the \( k \)th influence factor
\[ A \] Weighted matrix \( A \)
\[ R \] Target reliability of the whole system
\[ R_i \] Reliability allocated of the \( i \)th module
\[ \Delta E_{out} \] Number of the corresponding change of a model in propagation for output
\[ \Delta E_{in} \] Number of the corresponding change of a model in propagation for input
\[ VI \] Variety index
\[ CPI \] Change propagation index

However, it cannot fully adapt to the reliability allocation of the early design phase with incomplete and uncertain product information.

The mentioned method tends to emphasize on only one factor in reliability allocation. However, more than one factor should be considered in reliability allocation, such as complexity, cost and working environment. Thus, reliability allocation is essentially similar to multiple criteria decision making (MCDM). Furthermore, decision making trial and evaluation laboratory (DEMATEL), AHP, as well as the analytic network process (ANP) have also become typical approaches used in solving reliability allocation [4–7]. Meanwhile, due to the insufficient information in early product design stage, the product reliability allocation tends to rely on expert evaluation, such as the integrated factors method (IFM), the comprehensive reliability allocation method, and the method based on cubic transformed functions of failure mode and effects analysis [8,9]. And given the fuzzy nature in the experts' knowledge, fuzzy linguistic words, such as low, moderate and high, are more suitable to be used in the experts' evaluation [10,11].

For instance, Wu et al. [12] proposed a method using fuzzy reasoning Petri net which was of great practical significance for the reliability allocation where the design information is incomplete and uncertain. Similarly, Sri Ramdas et al. [2] proposed a fuzzy arithmetic for reliability allocation which offered a greater potential for further extension by cooperating relative importance of engineering attributes. Unfortunately, these methods can be easily influenced by the expert's subjective opinion. Therefore, the AHP method was proposed but it is limited due to its inapplicability of reliability allocation at early design stage. Then, methods based on ME-OWA introduced the conditional parameter to overcome this difficulty [13]. Nevertheless, above traditional methods still cannot satisfy the reliability allocation demands for modern products.

Firstly, there are vast quantities of information needed in the product reliability allocation, especially the expert measurement data, but most traditional methods fail to access and manage the large amounts of measurement information efficiently and effectively. To address these problems, the ICN networking paradigm is employed in reliability allocation which pursues the flexible and scalable network use for ubiquitous contents in network caches by the content-based networking instead of the conventional connection-oriented networking [14,15]. Research on ICN has flourished in recent years and it attempts to shift from the current host-oriented Internet architecture to the information-oriented one. Wang et al. [16] proposed a collaborative in-network caching scheme with Content-space Partitioning and Hash-Routing and exploited the built-in caching capability of ICN. Cha et al. [17] proposed a distributed capability access control scheme for ICN to address the problems about multiple copies of contents in various network locations, and it is beneficial to enforce access control policies in ICN. Hence, more emphasis should be put on ICN to overcome the difficulties in storing, accessing and managing the measurement information on product reliability allocation.

Secondly, most traditional reliability allocation methods fail to consider the environmental attributes of products, such as carbon emissions and energy efficiency. With the rapid development of technology, requirements for the quality and functionality of industrial products have become increasing flexible. Furthermore, for the purpose of resource saving, in reliability allocation, energy conservation and emission reduction should be taken in to consideration to avoid some wasteful or excessive designs, such as unnecessary high product reliability and unreasonable product reliability apportionment. It is
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