Use of ARINC Approach method to evaluate the reliability assignment for mixed system

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Abstract: The reduction process, which will permit us to transform a mixed system into a sequential system in order to resolve the problem of reliability allocation for this type of system, will be used in this research to measure the reliability allocation for mixed systems.

1. Introduction

The vital importance of reliability in a number of systems draws many researchers to reliability engineering [1]. For design issues with reliability criteria, a lot of work has been performed, and a number of techniques have been used. According to Tzafestas in 1980, one of the undeniable phases in the design of such multi-component structures is the problem of using usable tools. most cost-effective way to increase overall system efficiency or decrease resource consumption while achieving specific reliability goals [2]. The variety of system configurations, resource limitations, and options for optimizing performance have prompted the creation and analysis of several optimization models. On a regular basis, surveys on improving reliability have been written. One of the most recent publications on the subject is Kuo et al. book. Several studies have been conducted to improve parallel–series systems, however, only a handful have focused on series–parallel systems. The bulk of these works are on Jensen's redundancy allocation system from 1968 [3]. use complex programming for series–parallel–series networks He believes the networks under scrutiny are made up of a series of blocks, each of which is made up of related technology that work in concert. In multi-state series–parallel systems, Marquez and Coit recently introduced a heuristic for allocating redundancy. They proposed a novel solution strategy that has a number of distinct advantages over conventional approaches to the problem [4, 5]. Levitin et al., Zuo Hoang Pham, and Venugopal all suggest solutions to the problem of redundancy optimization in general. The subject of this series–parallel systems is the reliability allocation problem, in which the reliability of the modules must be calculated in order to reduce the utilization of a resource under a reliability constraint. When several technologies of the same purpose are used in parallel, this issue occurs [5, 6].

2. Basic definitions and concepts

Definition (2.1) System [1]
A group of regularly ordered compounds that communicate in order to perform a With each other and with external components or other structures given purpose.

Definition (2.2) Reliability R(t) [7]
The probability that for a certain period of time the system will survive is established. This can be expressed as the time to system failure in terms of random variable $T$.

$$R(t) = \int_{1}^{\infty} f(t)\,dt$$

**Definition (2.3) Failure rate** [8]

Is the possibility of failure for each time unit in the extra time allocated, implying that the failure did not occur before time $t$, and hence the failure rate is the rate at which failure happens when $[t, \Delta t]$, where the Failure Rate Equation is used.

$$F_R = \frac{p[t \leq T < t + \Delta t \backslash T > t]}{\Delta t} = \frac{\Delta t R(t)}{\Delta t R(t)} = \frac{F(t + \Delta t) - F(t)}{F(t)}$$

**Definition (2.4) series system** [8]

The series system works only if all of its components are working. This system depends on both of them. Device elements are executed properly.

![Series System Diagram](image)

**Figure (2.1) Series system**

the reliability of the system is given by

$$R_{system} = R_{s1} \times R_{s2} \times \ldots \times R_{sn} = \prod_{i=1}^{R} R_{si}$$

**3. Mixed system**

This system is a combination of a parallel system and a series system, and we only break the system into a series and parallel to find each subsystem's reliability and complete to find the system's reliability [9].

![Mixed System Diagram](image)

**Figure (2.2) mixed system**
4. Reduction to Series Elements

This method involves replacing each parallel path systematically with an identical on Single path, and the structure is gradually reduced to one consisting only of component. In this section, will try to find the reliability function of mixed system Fig. (2.2) as the within steps [10,11].

**Step (1)**

\[
R_{cde} = 1 - [(1 - R_{cd})(1 - R_e)] \\
= 1 - [1 - R_g - R_{cd} + R_{cd}R_e] \\
= R_e + R_{cd} - R_{cd}R_e \\
= 0.90 + 0.64 - 0.58 = 0.96
\]

\[
R_{gh} = 1 - [(1 - R_g)(1 - R_h)] \\
= 1 - [1 - R_h - R_g + R_gR_h] \\
= R_h + R_g - R_gR_h \\
= 0.8 + 0.75 - 0.6 = 0.95
\]

**Step (2)**

\[
R_{bced} = R_b \times R_{cde} \\
= 0.75 \times 0.96 = 0.72
\]

\[
R_{ghf} = R_{gh} \times R_f \\
= 0.95 \times 0.65 = 0.62
\]
5. System reliability allocation

Reliability allocations for hardware or software systems will start immediately after the models for reliability have been developed. The initial values that are assigned to the system should be the values specified for the reliability metrics of the system, or a set of reliability related values that are more difficult to achieve than those specified [15]. For the functionality aspect, the more aggressive reliability values are often allocated to the system than the required ones.

\[ f(R_1, R_2, R_3, \ldots, R_n) \geq R \]  

(2.3)

where \( R \) is the goal for the reliability system, and \( R_1, R_2, R_3, \ldots, R_n \) is the reliability goal of each component, and \( f \) has a relationship between reliability system and its component and obtained from the reliability analysis of the system to be allocated [14]. The allocation of reliability is important in the overall reliability program especially when components or vehicles are under development and complex.

Among the advantages of reliability allocation, it is

1. Reliability allocations for hardware or software systems will start immediately after the models for reliability have been developed. The initial values that are assigned to the system should be the values specified for the reliability metrics of the system, or a set of reliability related values that are more difficult to achieve than those specified. For the functionality aspect, the more aggressive reliability values are often allocated to the system than the required ones [16, 17].
2. The parties are responsible for improving their reliability through the use of reliability techniques, better engineering designs, high quality manufacturing processes and rigorous and accurate testing methods.
3. Reliability allocations for hardware or software systems will start immediately after the models for reliability have been developed. The initial values that are assigned to the system should be the values specified for the reliability metrics of the system, or a set of reliability related values that are more difficult to achieve than those specified. For the functionality aspect, the more aggressive reliability values are often allocated to the system than the required ones [16, 17].
4. It is possible that output reliability allocation as input to other reliability tasks.
6. Use of ARINC Approach method

This method is based on a series of sub system with fixed failure rates so that the failure of any sub system causes the system to fail completely and that the task time of the component is equal to the time of the system task. It is assumed in this method that all components are connected in a series and independent from each other and widely distributed and have a common time in the test [18, 19]. In the reliability allocation we use the weighting factor as following:

1. We find weighting factors (Wi) for individual components where
   \[ W_i = \frac{\lambda_i}{\sum_{i=1}^{n} \lambda_i} \quad i = 1, 2, 3, \ldots, n \]  
   (2.4)

   Where \( \lambda_i \) is the failure rate of component \( i \) obtained from historical data or prediction [20]. The factors \( \lambda_i \) are the relative likelihood of failure. The larger the value of \( w_i \), the more likely the component is to fail. The failure rate goal assigned to a variable should then be proportional to the size of the weight, namely the value of the weight.

2. Find \( \lambda \) which is the maximum allowable failure rate where
   \[ \lambda_i = w_i \cdot \lambda \]  
   (2.5)

   And
   \[ \lambda = -\frac{\ln[R(t)]}{t} \]  
   (2.6)

3) We calculate the reliability

\[ R_i(t) = e^{-\lambda_i t} \]  
(2.7)

**Illustrative Example**

A computer consists of three sub-system having consecutive failure rates \( \lambda_1 = 0.015 \), \( \lambda_2 = 0.018 \), \( \lambda_3 = 0.023 \), failures per month, select the requirements of reliability through (36) months in service to achieve total reliability it is (0.98).

**Solution**

By equation (2.4) we get:

\[ W_i = \frac{\lambda_i}{\sum_{i=1}^{3} \lambda_i} \quad i = 1, 2, 3 \]

\[ W_1 = \frac{0.015}{0.015 + 0.018 + 0.023} = 0.27 \]

\[ W_2 = \frac{0.018}{0.015 + 0.018 + 0.023} = 0.32 \]

\[ W_3 = \frac{0.023}{0.015 + 0.018 + 0.023} = 0.41 \]

Now, by using equation (2.7) find \( \lambda \) where:

\[ \lambda = -\frac{\ln(0.98)}{36} = 5.612 \times 10^{-4} \]
\[ \lambda_i = W_i \cdot \lambda \]
\[ \lambda_1 = 0.26 \times 5.612 \times 10^{-4} = 1.45912 \times 10^{-4} \]
\[ \lambda_2 = 0.32 \times 5.612 \times 10^{-4} = 1.79584 \times 10^{-4} \]
\[ \lambda_3 = 0.41 \times 5.612 \times 10^{-4} = 2.30092 \times 10^{-4} \]

Now, we find the reliability per component by using equation (2.7) we get
\[ R_1(36) = e(-1.0866 \times 10^{-4} \times 36) = 0.9989 \]
\[ R_2(36) = e(-1.79584 \times 10^{-4} \times 36) = 0.9868 \]
\[ R_3(36) = e(-2.30092 \times 10^{-4} \times 36) = 0.9983 \]

Now the reliability at (36) months is
\[ R(36) = R_1(36) \times R_2(36) \times R_3(36) = (0.9989)(0.9868)(0.9983) = 0.98 \text{ reliability required.} \]

Conclusions
This paper has clearly shown that the reduction method is useful to convert mixed systems Fig. (2.2) to its equivalent series form Fig. (2.5), it has been found that the reliability allocation for mixed systems can increase or improve its reliability by using ARINC Approach method because this method addresses the problem of allocating reliability to series systems only.

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