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Using of Genetic Algorithm to Evaluate Reliability Allocation and Optimization of Complex Network

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Abstract
In this paper the allocation of reliability and optimization has been calculated for each component of the complex system. Use (genetic algorithm) to solve the problem of allocation and to optimize system reliability. Also discussed are the three expense functions (exponential behavior with feasibility factor model, exponential behavior model and logarithmic model). The reliability importance of each component of the system was calculated after solving the allocation problem. The aim of this paper was to compare the results of the three cost functions by using GA in terms of reliability allocation and optimization, accurate reliability, reliability importance, and then whatever is more efficient than another.

Keywords: Reliability Allocation; Reliability Optimization; Allocation, Reliability importance, Genetic algorithm.

1. Introduction

Within this paper we looked at the durability of the complex device installed[9,10]. This method was found to be effective with the use of minimal paths via matrices of relation. (Removal of minimum path nodes) and Boolean algebra to acquire all routes [3, 6, 11 , 12,18].

The aim of seeking a reliability feature is to obtain details about the safety of running the complex device mounted. In this paper we also look at

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allocating optimal efficiency as a mathematical issue given the networks' roots. The reliability standards are optimized for each complex component of the system and based on locational importance. The aim is to achieve system reliability while reducing overall costs and improving longevity of the system[5, 7 , 8]. Many components can involve a high allocation, which differs from component to component, depending on the position of each component in the system, to improve the overall reliability. The engineers face several challenges in the cycle of upgrading mechanical and electrical structures [4, 6, 14]. This paper reflects on allocating and maximizing the functionality of dynamic processes and the expense in any height, weight or other quantities expressed by the device. This component 's functionality depends on two basic requirements: Firstly, The model must be cost-effective as a foundation for input item reliability. The parameters of the proposed cost parameter may be modified. This lets the engineers evaluate the assignments for all the devices and how to obtain the minimum efficiency needed for each part of the machine. Second , the model needs to balance analytical reliability of the input system too. In plain system, That some situations pose a major problem in complex systems which can become a major challenge. The cost was calculated by the exponential behavior with feasibility factor, exponential behavior model and logarithmic model the results were obtained using the Genetic algorithm which helps to solve the optimization problems in the complex system.

2. Optimization of complex system

Consider a complex system composed of connected elements [1, 3, 15]. We are using the Statements: $0 \leq R_i \leq 1$ is the component reliability i ; $C_i(R_i)$ The Component Costs i ; $C(R_1,\ldots,R_n) = \sum_{i=1}^{n} a_i\, c_i$ (Ri) The Component Costs $a_i > 0$; R_s is the system reliability; RG Is System Reliability Goal.

Any part of the system has a unique functionality and there are lots of possibilities, often system parts offer us the same functionality but different reliability rates. The goal is to attain efficiency allocation of some or all parts of the system. The Q issue is included in nonlinear programming as a big problem[13, 15],a cost-and-function that can be evaluated and is a nonlinear limit. Q: Find

$$Minimize C(R_i, \dots, R_n) = \sum_{i=1}^{n} a_i C_i(R_i),\ a_i > 0, \qquad (2.1)$$

subject to

$$R_s \geq R_G,$$

$$0 \leq R_i < 1, i = 1, \dots, n$$

Assuming that the partial cost function is sensible $C_i(R_i)$ meets certain conditions[16] Increasing the positive, differentiated function $\left[\Rightarrow \frac{dC_i}{dR_i} \geq 0\right]$.

The preceding strategy aims at reaching an all-encompassing cost base [1, 5,17],
The System's stability cap is smaller, according to R_G.

3. Application to complex system

The complex device seen in Fig. (1) has the same main reliability for all of its computers at 90 per cent defined times [15]. The machine stability goal is 90 per cent at a defined period The polynomial of efficiency of the specified method was determined using the Minimal Path approach [14].

$$\begin{aligned} R_s = {} & R_2R_6 + R_1R_4R_9 + R_2R_5R_9 + R_2R_7R_{10} + R_3R_8R_{10} - R_2R_5R_6R_9 - R_2R_6R_7R_{10} - \\ & R_1R_2R_4R_5R_9 - R_1R_2R_4R_6R_9 - R_2R_3R_6R_8R_{10} - R_2R_3R_7R_8R_{10} - R_2R_5R_7R_9R_{10} \\ & + R_1R_2R_4R_5R_6R_9 - R_1R_2R_4R_7R_9R_{10} - R_1R_3R_4R_8R_9R_{10} + R_2R_3R_6R_7R_8R_{10} - \\ & R_2R_3R_5R_8R_9R_{10} + R_2R_5R_6R_7R_9R_{10} + R_1R_2R_4R_5R_7R_9R_{10} + \\ & R_1R_2R_4R_6R_7R_9R_{10} + R_2R_3R_5R_6R_8R_9R_{10} + R_2R_3R_5R_7R_8R_9R_{10} + \\ & R_1R_2R_3R_4R_5R_8R_9R_{10} + R_1R_2R_3R_4R_6R_8R_9R_{10} + R_1R_2R_3R_4R_7R_8R_9R_{10} - \\ & R_1R_2R_4R_5R_6R_7R_9R_{10} - R_2R_3R_5R_6R_7R_8R_9R_{10} - R_1R_2R_3R_4R_5R_6R_8R_9R_{10} - \\ & R_1R_2R_3R_4R_5R_7R_8R_9R_{10} - R_1R_2R_3R_4R_6R_7R_8R_9R_{10} + R_1R_2R_3R_4R_5R_6R_7R_8R_9R_{10}. \end{aligned}$$

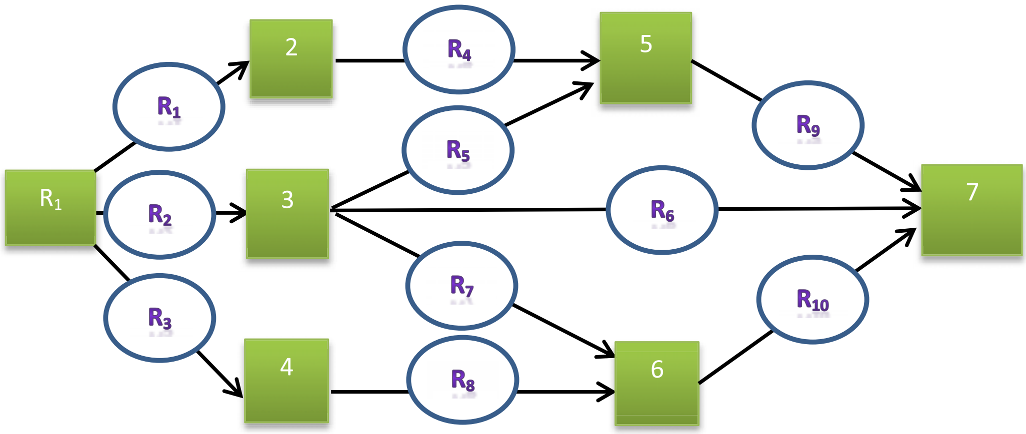

Figure 1: Complex network

4. Three significant cost models for reliability

4.1 Exponential behavior model with feasibility factor

Let $0 < f_i < 1$ be a feasibility factor [3,8,16], $R_{i,min}$ Be least reliable, and $R_{i,max}$ have the best efficiency. Another essential expense function is the exponential behavior.

$$C_i(R_i) = \exp[(1 - f_i)\frac{R_i - R_{i,min}}{R_{i,max} - R_i}],\ R_{i,min} \le R_i \le R_{i,max}\ , i = 1,2, \dots, n. \quad (4.1)$$

The optimization problem becomes:

$$Minimize\ C(R_i, \dots, R_n) = \sum_{i=1}^{n} a_i\ \exp[(1 - f_i)\frac{R_i - R_{i,min}}{R_{i,max} - R_i}],$$

$$i = 1,2, \dots, n.$$

Subject to:

$$R_s \ge R_G$$

$$R_{i,min} \le R_i \le R_{i,max}\ , i = 1, \dots, n\ .$$

Table 1: Summary table for optimal reliability allocation by using GA

Components	Reliability allocation

Component 1	0.9485
Component 2	0.9535
Component 3	0.9477
Component 4	0.9485
Component 5	0.9372
Component 6	0.9456
Component 7	0.9372
Component 8	0.9487
Component 9	0.9504
Component 10	0.9498
R_{system}	0.9989

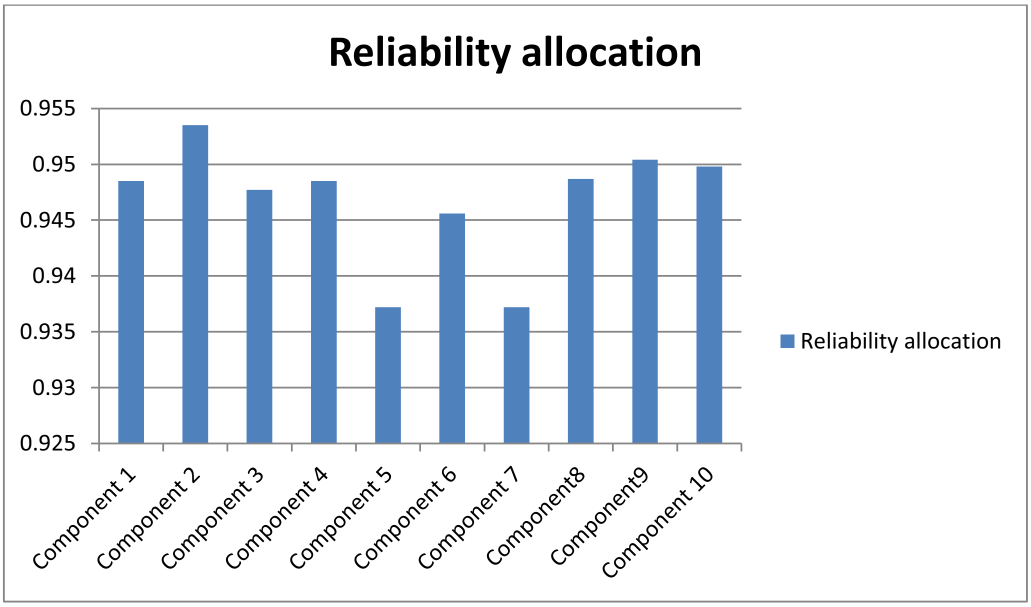

Figure 2: Reliability allocation for the given complex network by using exponential behavior model with feasibility factor model.

The findings were obtained using Genetic algorithm optimization as seen in Fig. (2). The findings revealed that all the elements of a complex structure are included in the distribution, and each relies on its machine role. The largest component R_2 allocation, whose meaning was (0.9535), while the lowest component R_7 allocation is (0.9372).

4.2 The exponential behavior model

Let $0 \leq R_i < 1, i = 1, \dots, n$ and a_i, b_i, are constants, i=1,2,…,n. Exponential behavior is the most important cost-function. It was proposed in the form of the[9,10]

$$C_i\,(R_i) = a_i e^{\left(\frac{b_i}{1-R_i}\right)}, a_i > 0\,, b_i > 0\,,\quad i = 1, \dots, n \qquad (4.2)$$

The problem with the optimization becomes:

$$\textit{Minimize}\;\; C(R_i, \dots, R_n) = \sum_{i=1}^{n} a_i\, e^{\left(\frac{b_i}{1-R_i}\right)}, i = 1,2, \dots, n.$$

Subject to :

$$R_s \geq R_G$$
$$0 \leq R_i < 1, i = 1, \dots, n$$

Table 2 Summary table for optimal reliability allocation by using GA

Components	Reliability allocation
Component 1	0.7914
Component 2	0.9900
Component 3	0.7856
Component 4	0.7893
Component 5	0.6836
Component 6	0.8111
Component 7	0.6807
Component 8	0.7851
Component 9	0.8382
Component 10	0.8320
R_{system}	0.9845

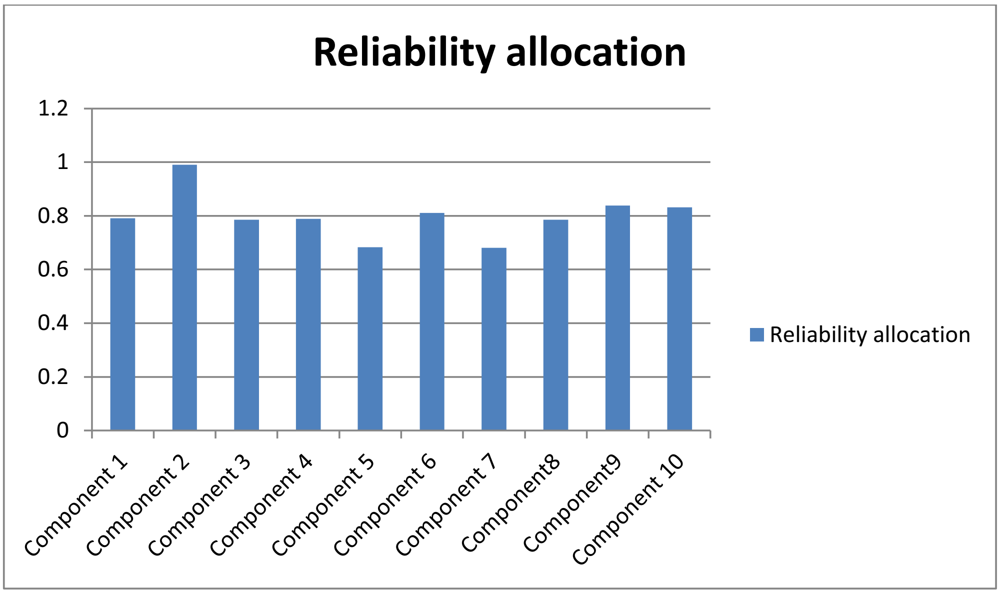

Figure 3: Allocation of reliability to complex system using exponential behavior model.

Results were obtained using Genetic Algorithm Optimization as seen in Fig. (3). The findings revealed that the distribution contains all the components of a complicated network, each depends on its device position. Component 2 has the largest value allocation (0.9900), while component 7 has the lowest value allocation (0.6807).

4.3 The Logarithmic model

Let $0 < R_i < 1, i = 1, \dots, n$ and a_i, are constants, i=,1,2,…,n. .Was suggested in the form of [2, 12]

$$C_i(R_i) = a_i \ln\left(\frac{1}{1-R_i}\right), a_i > 0\,,\ i = 1, \dots, n \qquad (4.3)$$

The optimization problem becomes:

$$Minimize\ \ C(R_i, \dots, R_n) = \sum_{i=1}^{n} a_i \ln\left(\frac{1}{1-R_i}\right),\ \ i = 1,2, \dots, n.$$

Subject to:

$$R_s \geq R_G$$

$$0 \leq R_i < 1, i = 1, \dots, n$$

Table 3: Summary table for optimal reliability allocation by using GA

Components	Reliability allocation
Component 1	0.5001
Component 2	0.9329
Component 3	0.5001
Component 4	0.5000
Component 5	0.5001
Component 6	0.8911
Component 7	0.5000
Component 8	0.5000
Component 9	0.5000
Component 10	0.5001
R_{system}	0.9006

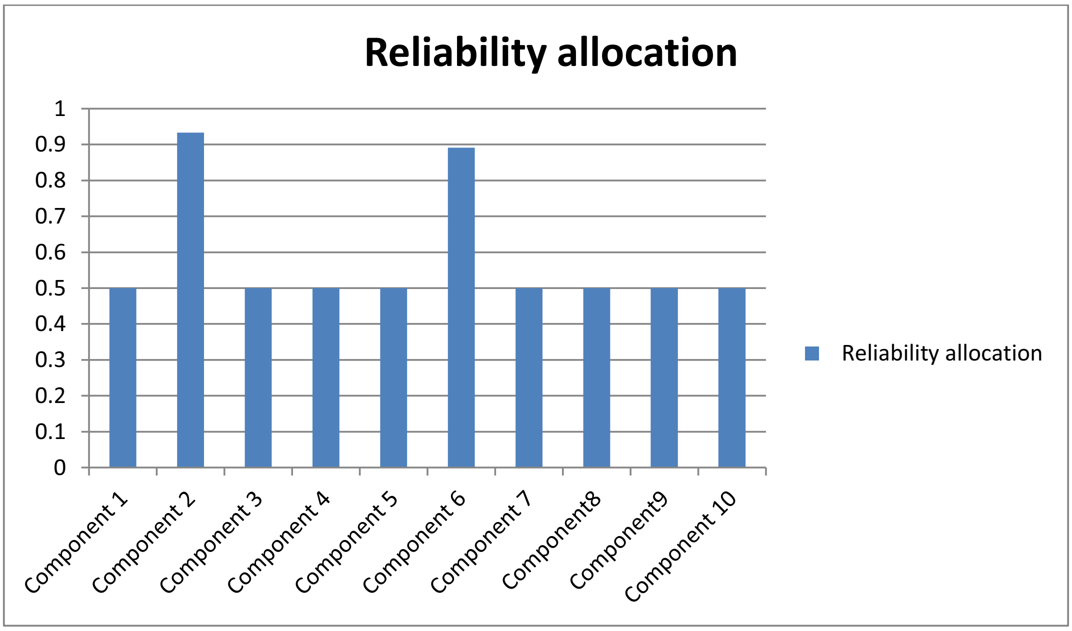

Figure 4: Reliability allocation for complex system by using logarithmic model

The findings were obtained using the Genetic algorithm In Fig4. The findings revealed that component 2 had the maximum allocation value was (0.9329), component 7 was the lowest allocation part (0.5000).

5. Calculating Reliability Importance

The importance of reliability, I, of component I in a system of n components:

$$I_R(i) = \frac{\partial R_s}{\partial R_i} \qquad (1.5)$$

Where Rs(t) is reliability of the system, $R_i(t)$ is reliability of the component and ∂ Is the derivative, partial. The meaning of the significance of reliability given by this equation depends on both a component 's reliability and its corresponding device location.

Example 1.1: Find a ten-component complex device with reliability in Fig.1. Use Eq. (1.5), the value of reliability for each component may be attained.
Purpose: The results obtained for each component of complex system were by applying the Eq. (1.5) to the reliability function of the system and the results were as follows:

After the allocation of reliability values for each part of the device has been resolved by fixing them in the above derivatives where the findings are of reliability significance as seen in the following table.4

Table 4: Summary table for reliability importance of GA of given system

Components	Feasibility factor model	Exponential behavior model	Logarithmic model
Component 1	0.006	0.014	0.023
Component 2	0.021	0.219	0.714
Component 3	0.006	0.013	0.023
Component 4	0.006	0.014	0.023
Component 5	0.003	0.016	0.026
Component 6	0.003	0.07	0.441
Component 7	0.003	0.016	0.026

Component 8	0.006	0.013	0.023
Component 9	0.009	0.048	0.058
Component 10	0.009	0.046	0.058

6. Results and discussions

6.1 Results of reliability allocation

We implemented three of the above cost functions. All results were inside the solution area but the results were better when utilizing the exponential behavior cost-function model with the feasibility factor model as seen in the table below:

Table 5: Summary table for optimal reliability allocation of the three cost functions by using GA

Component	Feasibility factor model	Exponential behavior model	Logarithmic model
Component 1	0.9485	0.7914	0.5001
Component 2	0.9535	0.9900	0.9329
Component 3	0.9477	0.7856	0.5001
Component 4	0.9485	0.7893	0.5000
Component 5	0.9372	0.6836	0.5001
Component 6	0.9456	0.8111	0.8911
Component 7	0.9372	0.6807	0.5000
Component 8	0.9487	0.7851	0.5000
Component 9	0.9504	0.8382	0.5000
Component 10	0.9498	0.8320	0.5001
R_{system}	0.9989	0.9845	0.9006

6.2 Results of reliability importance

The process of calculating the importance is based on the reliability system derivation which use Eq. (1.5). The results by using cost function (feasibility factor model) were as follows: The value of Better importance was given to compound R_2 (0.21) and less important to compound R_7 (0.003), while
the results by using cost function (the exponential behavior model) The value of Better importance was given to compound R_2 (0.219) and less important to compound R_3 (0.013) and the results by using cost function (the Logarithmic model) The value of Better importance was given to compound R_2 (0.7141) and less important to compound R_3 (0.023).

7. Conclusion

The stability optimization of a given complex network was addressed in this article. System optimization problem using engineering concepts to assign reliability to each component of the system. The problem was also addressed as a nonlinear programming problem, with three cost functions and work constraints (complex system reliability). Using the Genetic algorithm, the problem of reliability allocation was addressed and the results were compared and we concluded that the best model of the three cost functions given is the feasibility factor model as shown above where the Rs value is 0.9989. This is obvious to us that component 7 has the lowest allocation, while component 2 has the maximum allocation because of the position of certain components within the complex structure. This model has the benefit that any system, despite some difficulty, will be able to apply the mathematical methods used

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