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Using of particle swarm optimization (PSO) to addressed reliability allocation of complex network

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Abstract

This paper focuses on the reliability of complex system that has been measured as a complex system using minimal paths. The reliability of this system has been assigned to research the possible approaches of the assignment reliability values based on reducing the total cost of this method. The results originally included:

(i) Three cost functions were used to measure the cost of the complex system: First, the exponential behavior model with the feasibility factor model. Second, the exponential behavior model. Third, the logarithm model.

(ii) The reliability of every component of the system was calculated using Particle Swarm algorithm to solve the problems of optimizing the given reliability of the complex system.

Keywords: Reliability Allocation, Reliability Optimization, Allocation, the Particle Swarm Optimization.

1. Introduction

In this paper we examined the reliability of the installed complex system [9, 10]. This system was found to be reliable by using minimal paths through connection matrices. (Removal of nodes to generate minimal paths) and Boolean algebra to obtain all paths [3, 6, 11, 12].

The purpose of finding a reliability function is to get information about the safety of operating the installed complex system. In this paper we also look at the allocation of optimal reliability as a mathematical problem despite the origins of the networks. The reliability standards for each complex component of the system are optimized and based on location importance. The aim is to achieve system reliability while reducing the overall cost and enhancing system reliability durability [5, 7, 8]. Some components can involve a high allocation varying from component to component depending on the position of each component in the system in order to improve the degree of overall reliability. In the process of improving mechanical and electrical systems, the engineers face many problems [4, 6, 14]. This paper focuses on allocating and enhancing the reliability of complex systems, and the cost of the system represented either by size, weight or other amounts. The reliability of this component depends on two fundamental requirements: First, the model has to be cost as a basis for the reliability of the input element. You can change the parameters of the proposed cost parameter. This helps the engineers to review the allocations for all the systems and prepare how to achieve the minimum reliability needed for each machine part. Second, the model also needs to balance input system analytical reliability. In simple systems, that some cases pose a major problem which can become a major challenge in complex systems. The cost was determined by the exponential behavior with feasibility factor, exponential behavior model and logarithmic model the results were achieved using the Particle Swarm 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 use the Statements: $0 \leq R_i \leq 1$ is the component reliability i ; $C_i(R_i)$ The Component Costs i ; C(R_1,…,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.

Every part of the system has a unique functionality and there are many possibilities, many system parts give us the same functionality with different levels of reliability. The aim is to achieve the allocation of reliability to some or all parts of the system. The Q question is included as a major problem in nonlinear programming [13, 15], a cost-and-function that can be evaluated and is a nonlinear limit. Q: Find

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

subject to

$$R_s \geq R_G,$$

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

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

The goal of the previous plan is to achieve an all-encompassing cost base [1, 5],
The reliability limit for the system is lower, subject to R_G.

3. Application to complex system

The complex system represented in Fig. (1) has the same primary reliability for all its computers at specified times of 90% [15]. The system reliability objective at a specified time is 90%. The reliability polynomial of the given system was calculated by using the approach to minimal path [14].

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

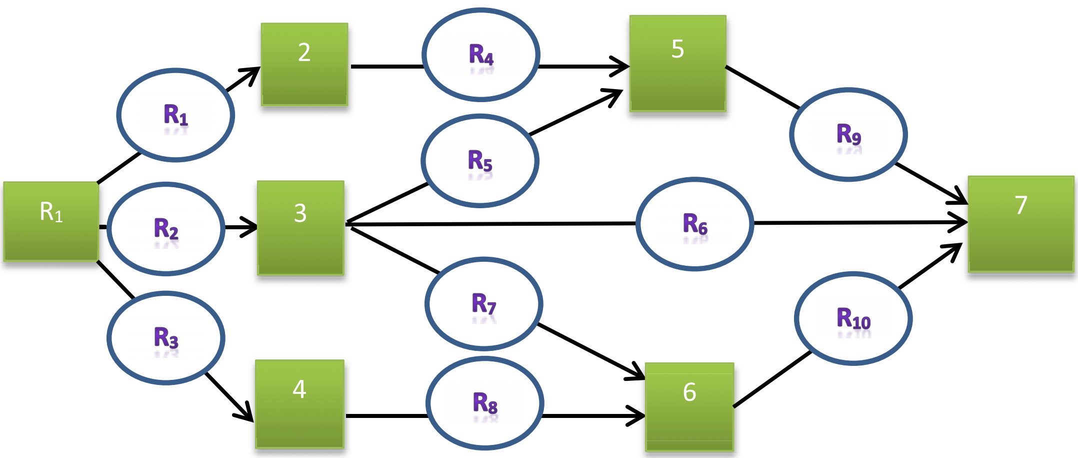

Figure 1: Complex network

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], $R_{i,min}$ be minimum reliability and $R_{i,max}$ be maximum reliability. Exponential behavior is another important cost function.

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

The optimization problem becomes:

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

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

Subject to:

$$R_s \geq R_G$$

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

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

Components	Reliability allocation
Component 1	0.7975
Component 2	0.8437
Component 3	0.7812
Component 4	0.5145
Component 5	0.5452
Component 6	0.7923
Component 7	0.6523
Component 8	0.7162
Component 9	0.7960
Component 10	0.6884
R_{system}	0.9019

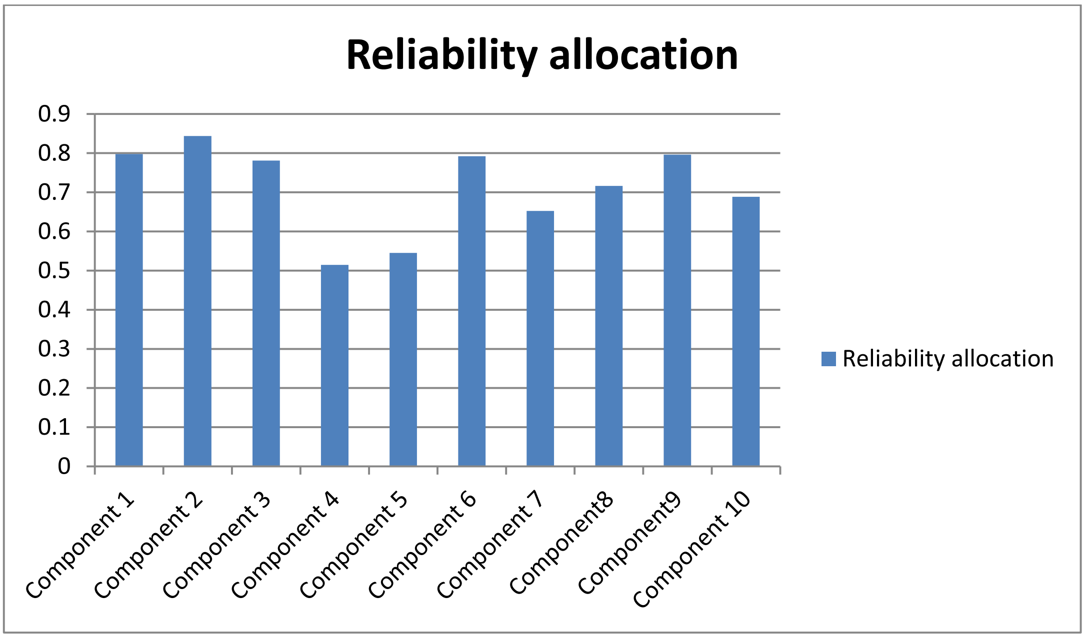

Figure 2: Reliability allocation for the given complex network by using exponential behavior model with feasibility factor model.

The results were obtained using the Optimization of Particle Swarm as shown in Fig. (2). The results showed that the allocation involves all the components of a complex system and each depends on its system position. The highest allocation of **component 2**, the value of which was (0.8437), while the lowest allocation of **component 4** is (0.5145).

4.2 The exponential behavior model

Let $0 \le R_i < 1, i = 1, \dots, n$ and a_i, b_i, are constants, i=1,2,…,n. The most significant cost-function is exponential behavior. It was suggested by the [9, 10], in the form

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

The problem with the optimization becomes:

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

Subject to :

$$R_s \ge R_G$$

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

Table 2 Summary table for optimal reliability allocation by using PSO

Components	Reliability allocation
Component 1	0.7994
Component 2	0.8556
Component 3	0.6808
Component 4	0.5191
Component 5	0.6021
Component 6	0.6530
Component 7	0.7393
Component 8	0.7558
Component 9	0.8119
Component 10	0.7741
R_{system}	0.9012

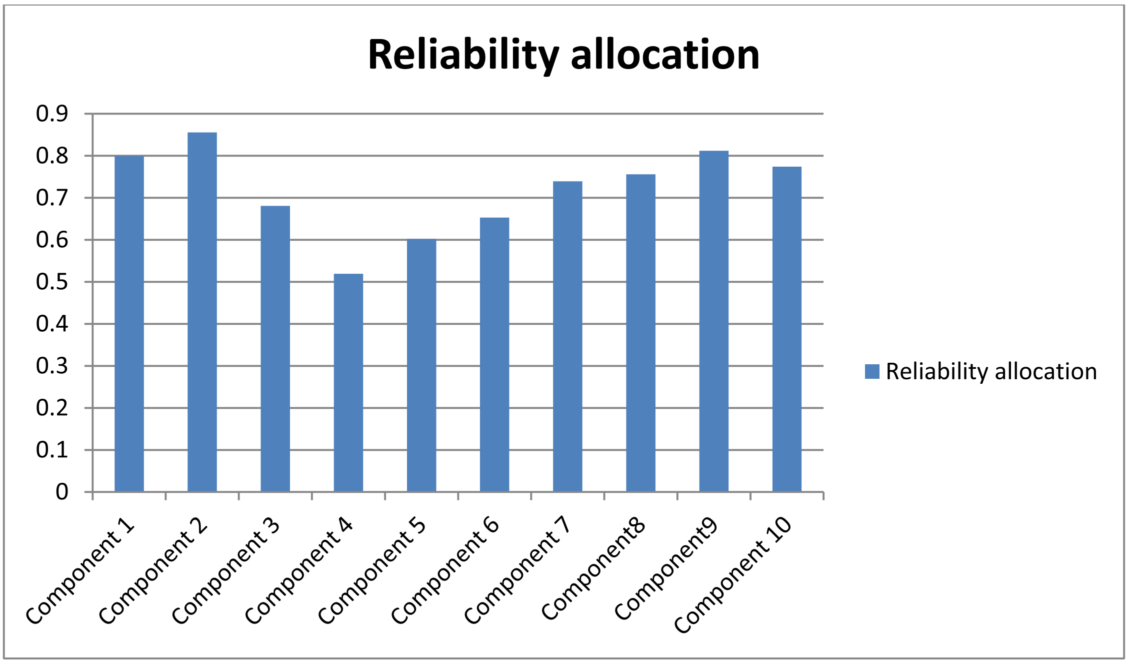

Figure 3: Reliability allocation for complex system by using exponential behavior model.

The results were obtained using the Optimization of Particle Swarm as shown in Fig. (3). The results showed that the allocation includes all of a complex system's components and each depending on its location in the system. **Component 2** have highest allocation which was value is (0.8443), while **component 4** which was lowest allocated which was value is (0.5191).

4.3 The Logarithmic model

Let $0 < R_i < 1, i = 1, \dots, n$ and a_i , are constants, i=,1,2,…,n. .It was proposed by [2, 12], in the form

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

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 PSO

Components	Reliability allocation
Component 1	0.671
Component 2	0.8961
Component 3	0.7368
Component 4	0.5138
Component 5	0.7413
Component 6	0.6321
Component 7	0.6858
Component 8	0.6742
Component 9	0.7666
Component 10	0.7845
R_{system}	0.9001

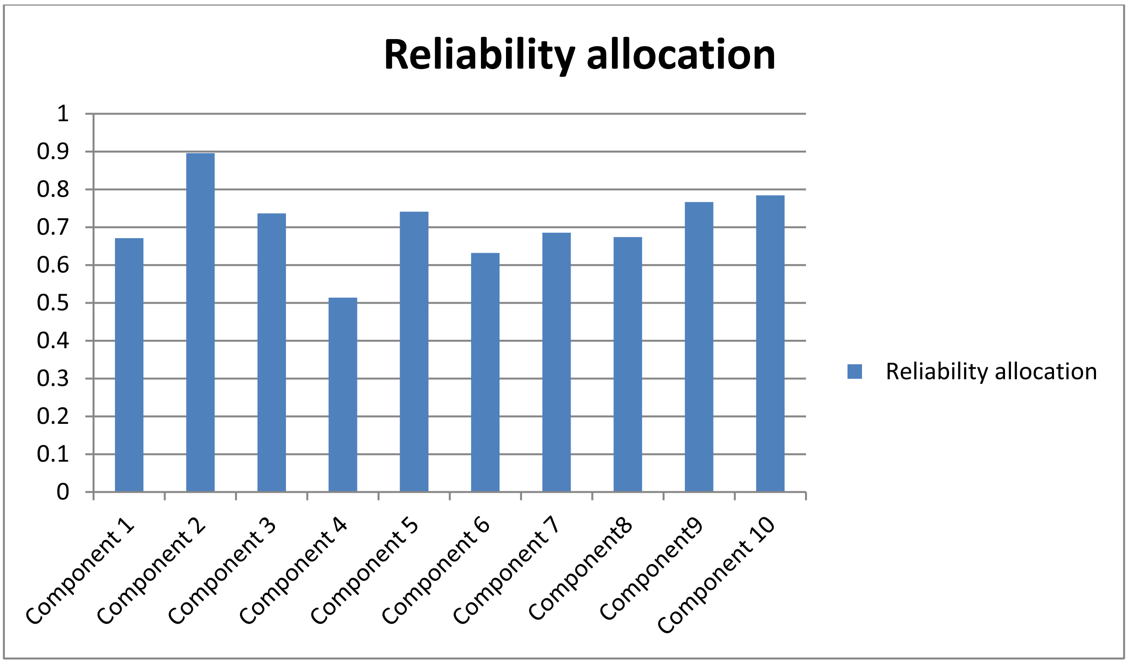

Figure 4: Reliability allocation for complex system by using logarithmic model

The results were obtained using the PSO. In Fig. (4) The results showed that the **component 2** that have highest allocation which was value is (0.8961), while **component 4** which was lowest allocated (05138).

5. Discuss the results

We applied three cost functions above. All findings were within the solution region but the findings were stronger by using the exponential behavior cost-function model with the feasibility factor model as shown in the table below:

Component	Feasibility factor model	Exponential behavior model	Logarithmic model
Component 1	0.7975	0.7994	0.671
Component 2	**0.8437**	**0.8556**	**0.8961**
Component 3	0.7812	0.6808	0.7368
Component 4	**0.5145**	**0.5191**	**0.5138**
Component 5	0.5452	0.6021	0.7413
Component 6	0.7923	0.6530	0.6321
Component 7	0.6523	0.7393	0.6858
Component 8	0.7162	0.7558	0.6742
Component 9	0.7960	0.8119	0.7666
Component 10	0.6884	0.7741	0.7845
R_{system}	**0.9019**	0.9012	0.9001

6. Conclusion

This paper has been discussed the reliability optimization of a given complex network. the system optimization problem using engineering concepts to allocate the reliability of each system component. The issue was also discussed as a nonlinear programming problem with three cost functions and work constraints (reliability of complex systems). Using optimization of particle swarm, the reliability allocation problem was addressed and the results were compared and we concluded that the best model of the given three cost functions is **feasibility factor model** as shown above where the value of $\boldsymbol{R_s}$ is 0.9019. Likewise, the issue of reliability allocation made it clear to us that **component 2** got the highest allocation, while **component 4** got the lowest allocation, due to the locations of these components in the complex system. This model has the advantage that every program would be able to implement the mathematical techniques used with great complexity.

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