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Neighborhood search algorithm for optimal reliability allocation with cost-reliability data for components

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Abstract

In this study, the concept and performance of the neighborhood search algorithm (NSA) are applied. The reliability allocation for each component of the complex network was calculated. The reliability of the system should be increased and allocation problems must be avoided. The total cost of the system also be calculated using the neighborhood search algorithm with an exponential cost function and a feasibility factor. This study aims to discuss and evaluate the results NSA by determining and accurately calculating reliability and total cost, good and fast results werer obtained by using algorithm.

Subject Classification: *54C55, 55M15.*

Keywords: *Neighborhood optimization, Algorithm, Reliability, Reliability allocation, Feasibility factor.*

1. Introduction

Optimization problems often have nonlinear objective functions with strict equality and inequality constraints. Many optimization problems are solved by algorithms, which are considered better than traditional methods because of the significant challenges they face. So, will be applied the algorithm called NSA with a new idea based on the basis of searching the neighborhoods of each point of the vector from the right and left to find new solutions from which the best one can be chosen in each iteration. One of the advantages of this method is that it brings us closer to good solutions and optimal solutions that are far from the best solution and are of the same quality. High stability because it moves in a

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very small area, where a set of acceptable non-zero solutions is taken, and the median is the best solution after arranging the terms from highest to lowest [1-4].

2. Optimization of complicated systems

Consider a complex system with components interlinked in terms of reliability [5, 6]. Utilize the notes provided below:

R_s: system's reliability;

$$0 \leq R_i \leq 1;\ i = 1,2,\dots,10;$$

$C_i(R_i)$: costs of element i;

$C(R_1,\dots,R_n) = \sum_{i=1}^{n} a_i c_i(R_i)$: total system costs, ($a_i > 0$);

R_G = systems reliability objective.

The distinct modular structures of the system and the unique functionalities of individual components produce a variety of potential outcomes. An array of system components offers us identical capabilities, each exhibiting varying levels of reliability. The overarching objective is the system's capacity to appropriately distribute resources to specific or every component. Non-linear programming necessitates addressing challenges [4, 7, 9]. Although it is non-linear, the constraint is utilized as a functional purpose and entails costs that warrant investigation.

$$Min(R_1,\dots,R_n) = \sum_{i=1}^{n} a_i C_i(R_i),\ a_i > 0,$$

Subjected in: $R_G \leq R_S$

$$0 \leq R_i < 1,\ \text{where}\ i = 1,\dots,n \tag{1}$$

3. Complex system implementation

To evaluate the intricate system, it is essential to convert it into a more manageable network, akin to the transformation of an entity series into parallel networks. For series and parallel networks consisting of n elements, the reliability is, respectively:

$$R_s = \prod_{i=1}^{n} R_i \tag{2}$$

$$R_s = 1 - \prod_{i=1}^{n}(1 - R_i) \tag{3}$$

In this context, R_s signifies the reliability network, representing the reliability of the component [6, 8]. Through the equations, a comparison will be made between the reliability of each intricate network and the minimum paths provided.

$$R_s = 1 - \prod_{z=1}^{p}\left(1 - \prod_{j=\alpha}^{\omega} R_j\right) \tag{4}$$

Within the given framework, the symbol α represents index of starting element, whereas ω signifies the index of last element contained in a minimal path. The reliability of the intricate system displayed in Figure 1 is calculated using Eq. (4)

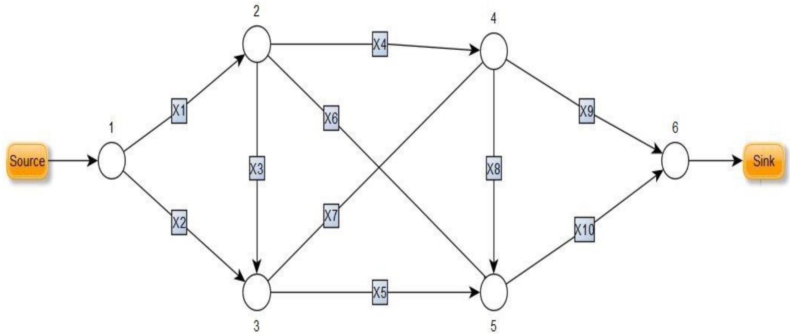

Figure 1
Complex network

Minimal path sets of a given complex system are:

$$S = \{\{x_1x_4x_9\}, \{x_1x_6x_{10}\}, \{x_2x_5x_{10}\}, \{x_2x_7x_9\}, \{x_1x_3x_5x_{10}\},$$
$$\{x_1x_3x_7x_9\}, \{x_1x_4x_8x_{10}\}, \{x_2x_7x_8x_{10}\},$$
$$\{x_2x_4x_5x_7x_{10}\}, \{x_2x_4x_5x_6x_9\}, \{x_1x_3x_7x_8x_{10}\}\}$$

and the reliability of our system is:

$$R_s = 1 - [1 - P_r\{x_1x_4x_9\}, \{x_1x_6x_{10}\}, \{x_2x_5x_{10}\}, \{x_2x_7x_9\}, \{x_1x_3x_5x_{10}\},$$
$$\{x_1x_3x_7x_9\}, \{x_1x_4x_8x_{10}\}, \{x_2x_7x_8x_{10}\}, \{x_2x_4x_5x_6x_9\},$$
$$\{x_1x_4x_5x_7x_{10}\}, \{x_1x_3x_7x_8x_{10}\}]$$

4. Algorithm of NSA

Step 1: Let ($N = 10^4$) and for each ($n = 1, ..., N$), generate random solutions ($R^n = \{R_1^n, R_2^n, \ldots, R_{10}^n\}$)

Step 1: Find the median of (R^n). For each ($n = 1, ..., N$), for some feasible solution (R^n) and let the new solution (R^m = text{median}[(R^1, R^2, ..., R^{10})) where (S) is the set of all feasible solutions (for all R in S).

Step 2: Enhance the solution (R^m) by generating new (4^{10}) solutions from (R^m) itself as follows:

Figure 2 shown the flowchart explains the iteration element to find out the comfortable element by using the neighboring algorithm.

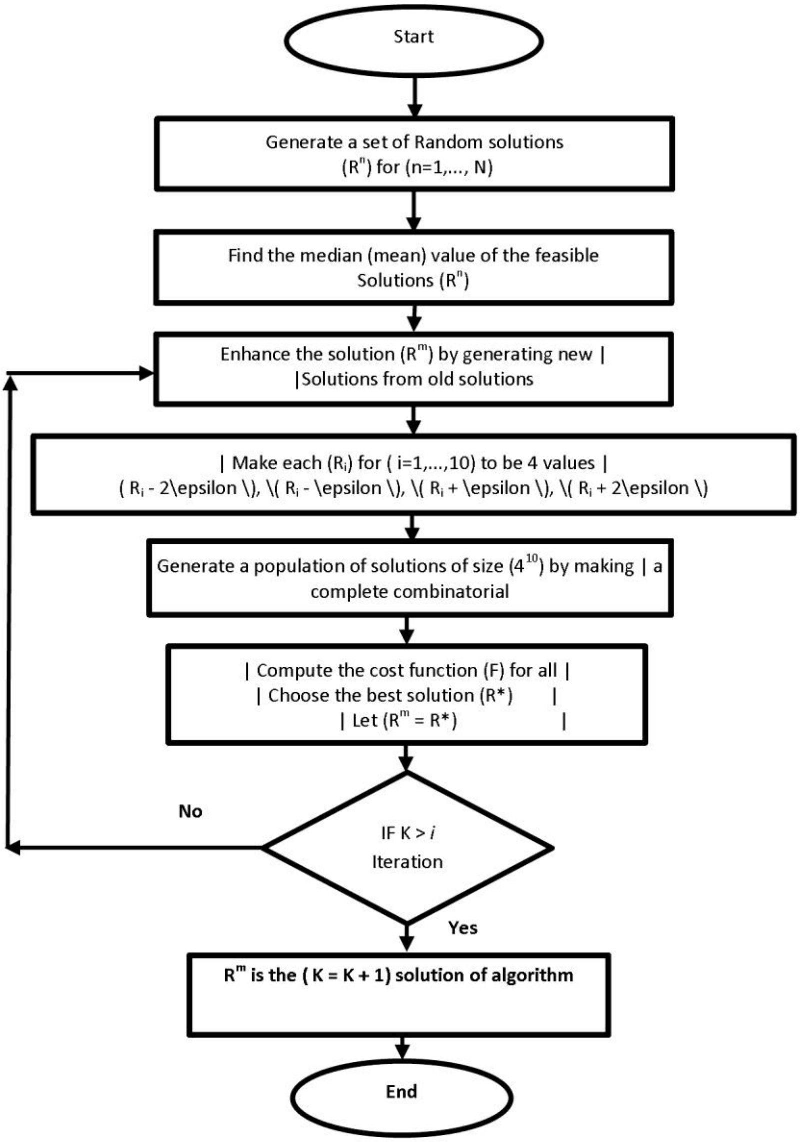

Figure 2
Flowchart explain the neighborhood algorithm

5. Exponential behavior model

The a_i and b_i constants were assume, where $0 \le R_i < 1, where\ i = 1,2,\dots,n$ [1, 4, 9] suggested on the below format.

$$C_i(R_i) = a_i e^{\left(\frac{b_i}{1-R_i}\right)}, b_i > 0\ , a_i > 0\ , \text{in which } i = 1,2,3,\dots,n$$

Problem optimizing emerges as:

Minimizing $$C(R_i, \dots, R_i) = \sum_{i=1}^{n} a_i \, e^{\left(\frac{b_i}{1-R_i}\right)},$$

S. t. $R_s \geq R_G$

$$0 \leq R_i < 1,$$

6. NSA with cost function

The Values of R_i, C_i, R_N and total cost C_N by SNO withe exponential cost function List in table 1.

Table 1

A summary Table for R_i , C_i and best values of R_N , C_N by NSA

R_i	Value of R_i	Value of C_i
R_1	0.731	0.1305
R_2	0.771	0.1503
R_3	0.8292	0.1673
R_4	0.8161	0.1551
R_5	0.8195	0.1569
R_6	0.8498	0.177
R_7	0.8066	0.1544
R_8	0.7621	0.135
R_9	0.6925	0.1335
R_{10}	0.7136	0.1373
R_s	0.99905	1.4981

7. Discuss the Results

We can make the following notes:

(1) $0.692 \leq Ri \leq 0.849$, for all i= 1,2, …….,10.

(2) $0.130 \leq Ci \leq 0.177$, for all i= 1,2, …….,10.

(3) The highest value of R_i was for the Sixth component, which is 0.849, while the lowest value of R_i was for the ninth Component, which is 0.692.

(4) R_6, R_3 are the highest values.

(5) $R_6 > R_3 > R_5 > R_4 > R_7 > R_2 > R_8 > R_1 > R_{10} > R_9$

(6) From Last observations we understand that the hired and sixth components are of greater importance than other components.

(7) The best value of reliability network is R_N=0.9990 which is excellent.

(8) The value of total cost is C_i=1.498

Two bar charts in Figures 3, and 4 shown the values of R_i, R_N and C_i, $C_{N,}$ respectively NSA with f_4.

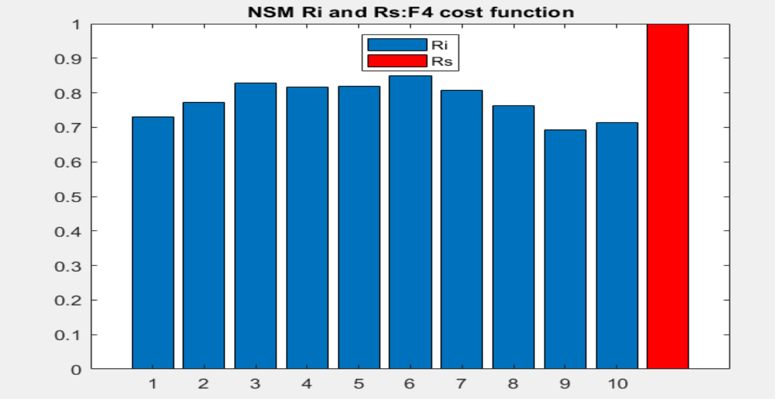

Figure 3
Values of R_i and best value of R_N by NS with f

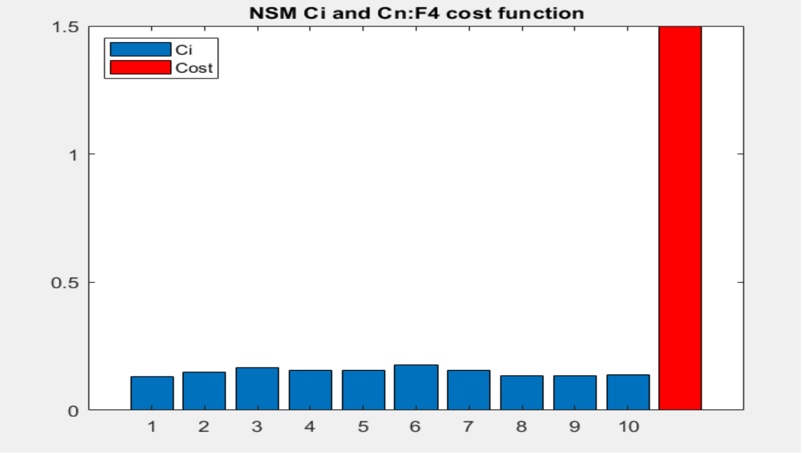

Figure 4
Values of C_i and C_N by NS with f

8. Conclusion

In the present research, addressed the calculation the reliability of each component using the neighborhood search algorithm. Through the above-mentioned method, the optimal allocation for each component was calculated, as well as the cost of all components of the system. The algorithm neighborhood search algorithm was distinguished by its simple concept, ease of implementation, and speed of convergence. By comparing the results obtained by it and other algorithms, it can be concluded that NSA it is a good algorithm for solving various complex optimization problems.

References

[1] E. K. Mutar, "Estimating the reliability of complex systems using various bounds methods," *International Journal of Systems Assurance Engineering and Management*, vol. 14, no. 6, pp. 2546–2558 (2023).

[2] Z. A. H. Hassan and E. K. Muter, "Geometry of reliability models of electrical system used inside spacecraft," in Proc. 2nd Al-Sadiq Int. Conf. on Multidisciplinary in IT and Communication Science and Applications (AIC-MITCSA), Baghdad, Iraq (2017).

[3] R. A. Fadhil and Z. A. H. Hassan, "Simple method to extract minimal cut sets of a direct network," *Journal of Interdisciplinary Mathematics*, vol. 26, no. 5, pp. 903–908 (2023).

[4] E. K. Mutar, "Determining the optimal design for complex systems using a reliability signature," *Journal of Intelligent & Fuzzy Systems*, vol. 46, no. 1, pp. 2999–3011 (2024).

[5] A. H. Alridha, A. M. Salman, and E. A. Mousa, "Numerical optimization software for solving stochastic optimal control," *Journal of Interdisciplinary Mathematics*, vol. 26, no. 5, pp. 889–895 (2023).

[6] Z. A. H. Hassan, C. Udriste, and V. Balan, "Geometric properties of reliability polynomials," U.P.B. Scientific Bulletin, *Series A: Applied Mathematics and Physics*, vol. 78, no. 1, pp. 3–12 (2016).

[7] M. K. Kadhim, F. A. Wahbi, and A. H. Alridha, "Mathematical optimization modeling for estimating the incidence of clinical diseases," *International Journal of Nonlinear Analysis and Applications*, vol. 13, no. 1, pp. 185–195 (2022).

[8] H. K. Hammood and Z. Al-Khafaji, "Some methods of finding minimum paths and the importance of reliability for a complex system," in Proc. 6th Iraqi Int. Conf. on Engineering Technology and Its Applications (IICETA 2023), Al-Najaf, Iraq, 2023.

[9] S. K. Mohamad and A. H. Kahleel, Optimizing Network Reliability in Dynamic or Rapidly-Changing Topologies (Trans.), *Babylonian Journal of Mathematics*, pp. 98–104 (2023). [Online]. Available: https://doi.org/10.58496/BJM/2023/019.

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