A COMPARATIVE STUDY BETWEEN GA AND PSO TO EVALUATE THE RELIABILITY OPTIMIZATION PROBLEM OF AN COMPLEX NETWORK

Hatem Kareem Sulaiman
Department of Mathematics, Directorate of Education Babylon, Babylon Iraq.
hatim19861986@gmail.com

Ghazi Abdullah
Department of Mathematics, College of Education for Pure Sciences, University of Babylon, Iraq.
ghazi717@yahoo.com, pure.ghazi.abd@uobabylon.edu.iq

Fouad Hamza Abd Alsharify
Department of Physics, College of Science, University of Babylon, Iraq.
sci.fouad.hamzah@uobabylon.edu.iq.

Zahir Abdul Haddi Hassan
Department of Mathematics, College of Education for Pure Sciences, University of Babylon, Iraq. mathzahir@gmail.com

Abstract :

In this study, each complex network component's allocation and optimization of reliability were calculated. The allocation problem should be solved, system dependability should be increased, and the system's overall cost should be calculated using techniques (such the genetic algorithm and particle swarm optimization). The three cost functions—the exponential behavior model with a feasibility factor, the exponential behavior model with logarithmic behavior—that were previously explained are also used. The significance of each system component's reliability was computed after the assignment problem was solved. This article's goal was to evaluate the outcomes of PSO and GA in terms of assigning and maximizing reliability, overall cost, precise reliability, relevance of reliability, and which is more efficient.

Keywords: Particle swarm optimization, Reliability allocation, Genetic algorithm, Reliability optimization, Evolutionary algorithm,.

1. Introduction

ResearchJet Journal of Analysis and Inventions
https://reserchjet.academiascience.org

The reliability of the complicated network was examined in the current article [1-25]. The reliability of this system was found by making use of the communication matrix's shortest paths. Boolean algebra is used to analyze all pathways and to generate minimal tracks [4–7]. The genetic algorithm was one of the algorithms used by John Holland, his colleagues, and students at the University of Michigan in the middle of the 1970s to solve the issue of allocation and optimization system reliability [7, 8]. GA frequently offers quite challenging solutions to a variety of issues. GA employs a variety of biological strategies, including recombination, mutation, cross-section, inheritance, and selection. In order to choose and produce people who are adapted to their surroundings, the General Assembly applies the "survival of the fittest" approach. When nonlinear functions, constraints, discrete and continuous variables, and both can be handled without the need for extra information, GA is used to address complicated design improvement problems. Fundamentally, an idea known as "optimization" makes it simple to address difficulties using optimization (Particle Swarm Optimization). An intelligence squadron was first proposed by Gerardo Penny and Wang Jing in 1989. They were motivated by ant colonies, fish education, grazing animals, and owing birds. The particle swarm optimization was created in the middle of the 1990s by Kennedy and Eberhardt [9]. Every particle in the PSO is considered a potential solution, and it is updated based on the right decision-making procedure. Although the PSO lacks evolutionary elements like junction and mutation, particles are given the capacity to fly through the problematic area by seeking the best present molecules. PSO has a wide range of advantages, including effectiveness, durability, simplicity, and use, which have led to its widespread use. PSO was discovered to need less arithmetic work than other random methods [10, 11]. While PSO has demonstrated its ability to tackle a variety of optimization problems, [12, 13] large-scale engineering problems still take a lot of time to solve. The comparison scale and the PSO vs. GA are also displayed. Included are closing remarks. The comparison of PSO and GA outcomes, as well as the efficiency of both algorithms, were the two main objectives of this research.

2. Optimization of the complex network

Consider an complex network consisting of components [14, 15]. We use the following notes:

$C_i(R_i)$ = element i cost;

$0 \leq R_i \leq 1$ = reliability i component;
R_s = reliability of the system;
$C(R_1, \dots, R_n) = \sum_{i=1}^{n} a_i c_i(R_i)$ is the total system cost, in which a_i is greater than 0;
RG = objective of systems reliability.

The modular structure of the system and the distinct operation of each component allow for a wide range of potential outcomes. Numerous system components offer us the same capability with varying levels of dependability. The ultimate goal is to have the system reliably distribute resources to all or particular components. Nonlinear programming depends on problems [9, 16, 17]. Although it is not linear, the restriction has a purpose and a cost that may be investigated:

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

Subject to:

$$R_s \geq R_G$$

$$0 \leq R_i < 1, in\ which\ i = 1, \dots, n \qquad (1)$$

3. Problem description

Any complicated network must first be reduced to a smaller network, like one whose components are connected in series or parallel, in order to compute its reliability. The outcomes show that a series network with n components is more dependable than a parallel network:

$$R_s = \prod_{i=1}^{n} R_i \qquad (2)$$

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

here R_N represents to the reliability network and R_i is the reliability of the component i [6,8].
From equations (1) and (2) we will compare the reliability of each complex network with p minimum paths that is given via

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

ResearchJet Journal of Analysis and Inventions
https://reserchjet.academiascience.org

here α is the index of first component and ω is the index of last component of a minimal path z.

Now, let's look at Fig. 1's complicated network reliability, below can be calculated by equation (3).

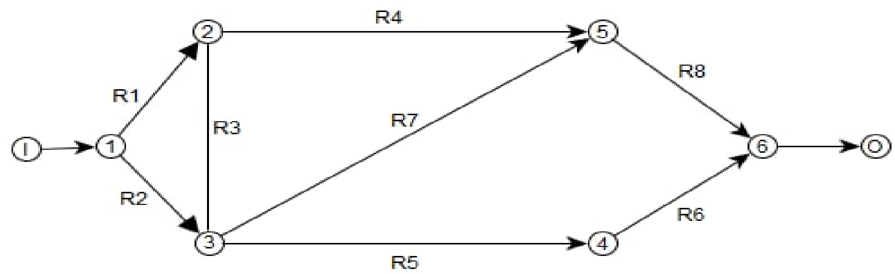


Figure 1: Complex Network

The sets:

$$S = \{\{R_1\ R_4R_8\},\{R_2R_5R_6\},\{R_2R_7R_8\},\{R_1R_3R_5R_6\},\{R_2R_3R_4R_8\},\{R_1R_3R_7R_8\}\}$$

$$R_s = 1-[1-p_r(R_1\ R_4R_8)]\times[1-p_r(R_2R_5R_6)]\times[1-p_r(R_2R_7R_8)] \times[1-p_r(R_1R_3R_5R_6)]\times[1-p_r(R_2R_3R_4R_8)]\times[1-p_r(R_1R_3R_7R_8)] \qquad (5)$$

Note: When the $i-$th component succeeds, then $R_i = 1$ and when it fails, then $R_i = 0\ \forall\ i = 1,\cdots,8$, these leads to

$R_i^n = R_i$ [7,9].

Equation (5) becomes the following polynomial when the note above is used.

$$\begin{aligned} R_S = {} & R_1\ R_4R_8 + R_2R_5R_6 + R_2R_7R_8 + R_1R_3R_5R_6 + R_2R_3R_4R_8 + R_1R_3R_7R_8 - R_1R_2R_3R_5R_6 \\ & -R_1R_2R_3R_4R_8 - R_1R_2R_3R_7R_8 - R_1R_2R_4R_7R_8 - R_1R_3R_4R_7R_8 - R_2R_3R_4R_7R_8 \\ & -R_2R_5R_6R_7R_8 + 2R_1R_2R_3R_4R_7R_8 - R_1R_2R_4R_5R_6R_8 - R_1R_3R_4R_5R_6R_8 \\ & -R_2R_3R_4R_5R_6R_8 - R_1R_3R_5R_6R_7R_8 + 2R_1R_2R_3R_4R_5R_6R_8 + R_1R_2R_3R_5R_6R_7R_8 \\ & +R_1R_2R_4R_5R_6R_7 + R_1R_3R_4R_5R_6R_7R_8 + R_2R_3R_4R_5R_6R_7R_8 - 2R_1R_2R_3R_4R_5R_6R_7R_8 \end{aligned}$$

4. Implementation of PSO

ISSN: 2776-0960 Volume 3, Issue 11 Nov., 2022

An evolutionary algorithm called PSO needs random number generation. The quantity and caliber of statistics produced have an impact on the PSO algorithm's outcome. The first iteration covers the whole search area. The fundamental PSO implementation is shown in the following figure.

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

The optimization problem becomes

$$\text{Minimize } C(R_i,\dots,R_i) = \sum_{i=1}^{n} a_i \exp[(1-f_i)\frac{R_i - R_{i,min}}{R_{i,max} - R_i}],$$
$$in\ which\ i = 1,2,\dots,n.$$

Subjected to :

$$R_s \ge R_G$$

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

Table 1: Optimum reliability allocation utilizing PSO and GA with an applied cost function.

Components	GA	PSO
R_1	0.94	0.94
R_2	0.94	0.95
R_3	0.93	0.93
R_4	0.93	0.93
R_5	0.94	0.96
R_6	0.94	0.93
R_7	0.93	0.84
R_8	0.95	0.94
R_{system}	0.9896	0.9817

ISSN: 2776-0960 Volume 3, Issue 11 Nov., 2022

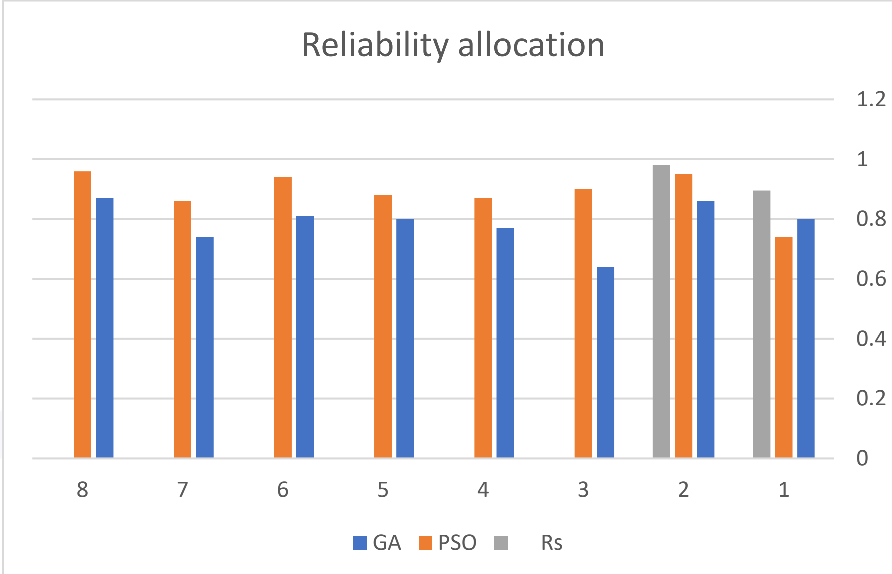


Figure 2: Allocation of reliability utilizing the given feasibility factor model and GA and PSO.

6.2 The model of exponential behavior

Assume the constants $a_i and\ b_i$, in which i=1,2,...,n and $0 \leq R_i < 1, in\ which\ i = 1, \dots, n$. [12-16] proposed it in the following format.

$$(R_i) = a_i e^{\left(\frac{b_i}{1-R_i}\right)} \quad , \quad b_i > 0\ , a_i > 0\ ,$$

$$in\ which\ \ i = 1,2,3, \dots, n$$

The optimizing problem emerges as:

Minimizing $C(R_i, \dots, R_i) = \sum_{i=1}^{n} a_i\ e^{\left(\frac{b_i}{1-R_i}\right)}, i = 1,2,3, \dots, n.$

Subjected to :

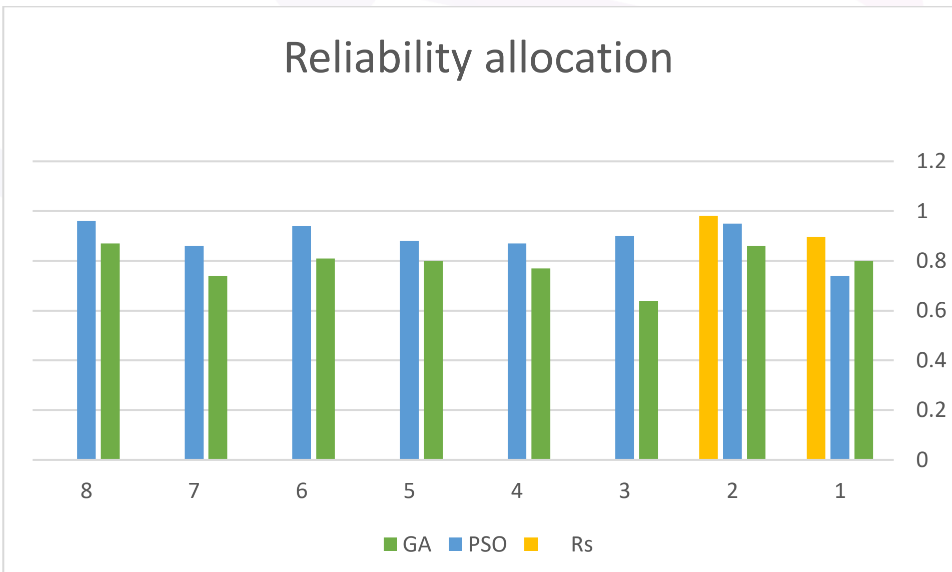
$$R_s \geq R_G$$

$$0 \leq R_i < 1,\ \ in\ which\ i = 1,2,3, \dots, n$$

Table 2 Optimum reliability allocation utilizing PSO and GA with an applied cost function.

Components	GA	PSO

R_1	0.80	0.74
R_2	0.86	0.95
R_3	0.64	0.90
R_4	0.77	0.87
R_5	0.80	0.88
R_6	0.81	0.94
R_7	0.74	0.86
R_8	0.87	0.96
R_{system}	0.8952	0.9808



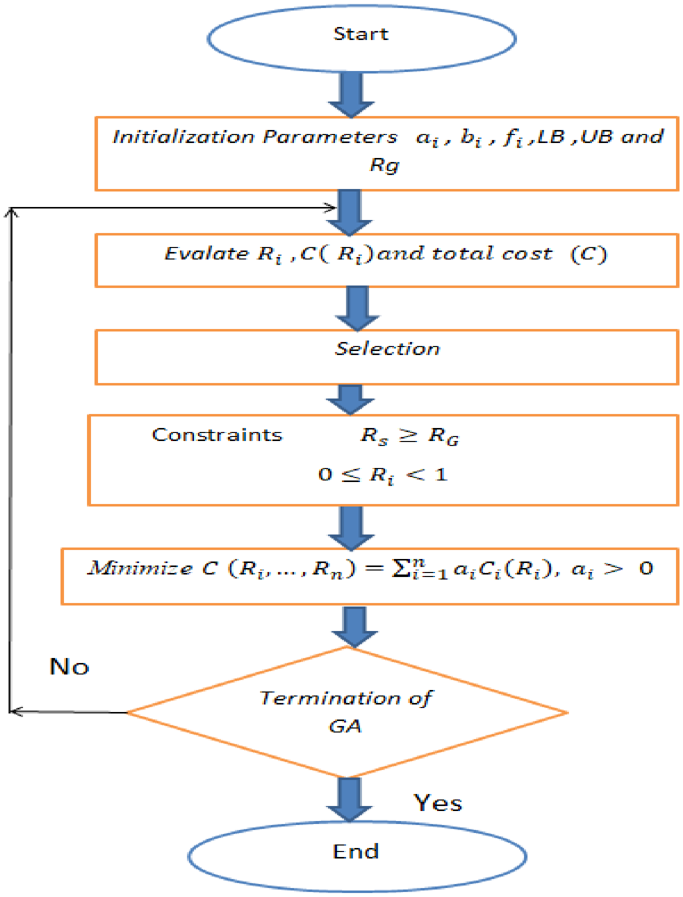


Figure 1.2: Flow chart of Genetic Algorithm

6. Three significant cost models for reliability

6.1 1 An exponential feasibility model based

Assume $0 < f_i < 1$ is a feasibility factor [12], $R_{i,max}$ is maximum reliability, and $R_{i,min}$ is minimum reliability.

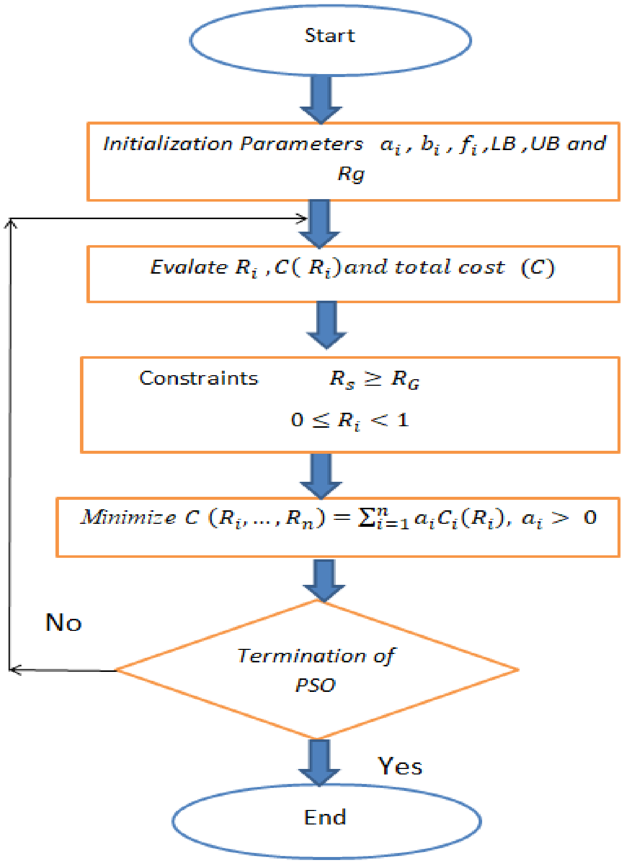


Figure 1.1 : Particle Optimization Flow Chart

5. Implementation of GA

GA uses a predefined fitness function after each iteration to create the fittest members. Figure 1.2. The basic GA flowchart is shown on the front. Figure 3: Utilizing GA and PSO to allocate reliability using the exponential behavior model.

6.3 The Logarithmic model

Assuming that $0 < R_i < 1$, *and* a_i are constants, *in which* $i = 1, \ldots, n$. [12, 16] proposed it in the following format.

$$C_i(R_i) = a_i \ln\left(\frac{1}{1-R_i}\right), a_i > 0\,,$$
$$in\ which\ \ i = 1, \ldots, n$$

The optimizing problem would become:

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

$$in\ which\ i = 1,2,3, \dots, n.$$

Subjected to :

$$R_s \geq R_G$$
$$0 \leq R_i < 1,\ \ in\ which\ i = 1,2,3, \dots, n$$

Table 3: Optimum reliability allocation utilizing PSO and GA with an applied cost function.

Components	GA	PSO
R_1	0.5	0.92
R_2	0.94	0.95
R_3	0.5	0.91
R_4	0.5	0.81
R_5	0.5	0.90
R_6	0.51	0.83
R_7	0.92	0.96
R_8	0.95	0.96
R_{system}	0.8929	0.9804

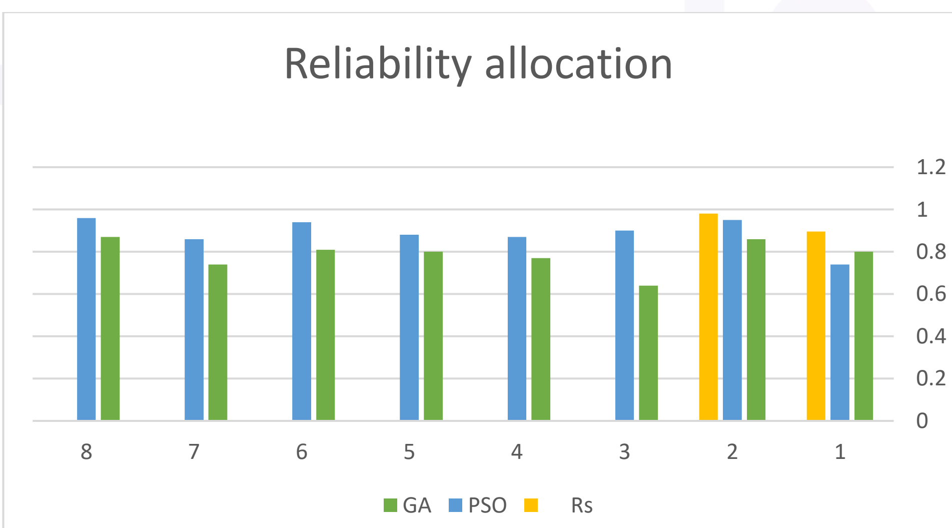


Figure 4: Utilizing GA and PSO to allocate reliability using the provided Logarithmic model

conclusions

In this paper, the optimal reliability allocation by to optimally distribute reliability for each component of the system was calculated using algorithms (GA and PSO), in addition to calculating the exact reliability Rs. After solving the problem of system's component assignment and optimization, the results are generally better in terms of PSO assignment than GA. The highest component allocation was through the use of the cost function (Exponential Behavior Model with Feasibility Factor) where Rs in the genetic algorithm it was equal to (0.9896), while in the Particle Swarm Optimization algorithm it was equal to (0.9817), The cost function logarithmic model was used to determine the lowest allocation to the system's parts; Rs in the genetic algorithm was equal to (0.8929) and (0.9804) in the particle swarm optimization technique, as indicated in Table (1, 2, 3).

References

[1] Z. A. H. Hassan, and E. K. Mutar, Geometry of reliability models of electrical system used inside spacecraft, 2017 Second Al-Sadiq International Conference on Multidisciplinary in IT and Communication Science and Applications (AIC-MITCSA), pp. 301-306, (2017).

[2] Z. A. H. Hassan, and V. Balan, Fuzzy T-map estimates of complex circuit reliability, International Conference on Current Research in Computer Science and Information Technology (ICCIT-2017), IEEE, Special issue, pp.136-139, (2017).

[3] Jula, Nicolae, and Cepisca Costin. Methods for analyzing the reliability of electrical systems used inside aircrafts. Recent Advances in Aircraft Technology. Intech Open, (2012).

[4] Z. A. H. Hassan, and M. A. K. Shiker, Using of Generalized Bayes' Theorem to Evaluate the Reliability of Aircraft Systems, Journal of Engineering and Applied Sciences, 13: 10797-10801, (2018).

[5] Z. A. H. Hassan, and E. K. Mutar, Evaluation the reliability of a high-pressure oxygen supply system for a spacecraft by using GPD method, Al-Mustansiriyah Journal of college of education, vol. special issue. pp. 993 -1004, 2 (2017).

[6] Z. A. H. Hassan, C. Udriste, and V. Balan, Geometric properties of reliability polynomials, U.P.B. Sci. Bull., vol. 78, no. 1, pp. 3-12, (2016).

[7] A. Kumar, A. Khosla, J.S. Saini and S. Singh, Meta-heuristic range based node localization algorithm for wireless sensor networks, in localization and GNSS (ICLGNSS), 2012 International Conference on IEEE, pp.1-7, 2012.

[8] X. Feng, X. Zhu, W. Zhao, and X. Li, Reliability of Electric Vehicle with Wind Turbine Based on Particle Swarm Optimization. Chemical Engineering Transactions, 66, 1291-1296, (2018).

[9] K., Sapna. A Comparative Study of Genetic Algorithm and the Particle Swarm Optimization. International Journal of Technology, 2.2: 21-24, (2010).

[10] N. Nedjah, L. dos Santos Coelho, and L.de Macedo Mourelle, Multiobjective swarm intelligent systems: theory experiences. Springer Science Business Media, vol.261 (2009).

[11] K. Saibal, C. S. Singh, and Amrit Pal, Comparative study of firefly algorithm and particle swarm optimization for noisy non-linear optimization problems. International Journal of intelligent systems and applications, 4.10: 50, (2012).

[12] S. Singh, Shivangna and E. Mittal, Range based wireless sensor nodes localization using PSO and BBO and its variants, in Communication Systems and Network Technologies (CSNT), 2013 International Conference on IEEE, pp. 309-315 (2013).

[13] G. Venter, and J. Sobieski, Particle Swarm Optimization, AIAA 2002-1235,43rd IAAA /ASME/ASCE/AHS/ASCStructures, Structural Dynamics, and Materials Conference, Denver, CO., April (2002).

[14] S. A. Abed, C. Udriste, and I. Tevy, Optimal reliability allocation for redundancy series-parallel systems, European Journal of Pure and Applied Mathematics, 10(4), 877-889 (2017).

[15] S. A. Abed, H. K. Sulaiman and Z. A. H. Hassan, (2019, September). Reliability Allocation and Optimization for (ROSS) of a Spacecraft by using Genetic Algorithm. In Journal of Physics: Conference Series (Vol. 1294, No. 3, p. 032034). IOP Publishing.

[16] S. A. K. Abbas and Z. A. Haddi Hassan, Increase the Reliability of Critical Units by Using Redundant Technologies, Journal of Physics: Conference Series, vol. 1999, no. 1, p. 012107, 2021/09/01 2021, doi: 10.1088/1742-6596/1999/1/012107.

[17] S. A. K. Abbas and Z. A. H. Hassan, Use of ARINC Approach method to evaluate the reliability assignment for mixed system, Journal of Physics: Conference Series, vol. 1999, no. 1, p. 012102, 2021/09/01 2021, doi: 10.1088/1742-6596/1999/1/012102.

ResearchJet Journal of Analysis and Inventions
https://reserchjet.academiascience.org

[18] F. H. Abd Alsharify and Z. A. Haddi Hassan, Computing the reliability of a complex network using two techniques, Journal of Physics: Conference Series, vol. 1963, no. 1, p. 012016, 2021/07/01 2021, doi: 10.1088/1742-6596/1963/1/012016.
[19] F. H. Abd Alsharify, G. A. Mudhar, and Z. A. Haddi Hassan, A modified technique to compute the minimal path sets for the reliability of complex network, Journal of Physics: Conference Series, vol. 1999, no. 1, p. 012083, 2021/09/01 2021, doi: 10.1088/1742-6596/1999/1/012083.
[20] G. Abdullah and Z. A. H. Hassan, Use of Bees Colony algorithm to allocate and improve reliability of complex network, Journal of Physics: Conference Series, vol. 1999, no. 1, p. 012081, 2021/09/01 2021, doi: 10.1088/1742-6596/1999/1/012081.
[21] L. A. A. Ameer issa and Z. A. Haddi Hassan, Use of a modified Markov models for parallel reliability systems that are subject to maintenance, Journal of Physics: Conference Series, vol. 1999, no. 1, p. 012087, 2021/09/01 2021, doi: 10.1088/1742-6596/1999/1/012087.
[22] G. Abdullah and Z. A. Haddi Hassan, 2020, Using of Genetic Algorithm to Evaluate Reliability Allocation and Optimization of Complex Network, IOP Conf. Ser.: Mater. Sci. Eng. 928(4) 0420333

[23] G. Abdullah and Z. A. Haddi Hassan, 2020, Using of particle swarm optimization (PSO) to addressed reliability allocation of complex network, J. Phys.: Conf. Ser. 1664 (1) 012125.
[24] G. Abdullah and Z. A. Haddi Hassan, 2021, A Comparison Between Genetic Algorithm and Practical Swarm to Investigate the Reliability Allocation of Complex Network, J. Phys.: Conf. Ser. 1818 (1) 012163.
[25] E. K. Mutar, and Z. A. H. Hassan, 2022, New properties of the equivalent reliability polynomial through the geometric representation, International Conference on Electrical, Computer and Energy Technologies (ICECET 2022), Prague-Czech Republic.

ResearchJet Journal of Analysis and Inventions
https://reserchjet.academiascience.org