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ANALYTICAL REVIEW ON THE MODERN OPTIMIZATION ALGORITHMS IN LOGISTICS

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Abstract: Optimization algorithms are used to reach the optimum solution from a set of available alternatives within a short time relatively. With having complex problems in the logistics area, the optimization algorithms evolved from traditional mathematical approaches to modern ones that use heuristic and metaheuristic approaches. Within this paper, the authors present an analytical review that includes illustrative and content analysis for the used modern algorithms in the logistics area. The analysis shows accelerated progress in using the heuristic/metaheuristic algorithms for logistics applications. It also shows the strong presence of hybrid algorithms that use heuristic and metaheuristic approaches. Those hybrid algorithms are providing very efficient results.
Keywords: Optimization algorithms, logistics, analytical review, heuristic, metaheuristic

1. INTRODUCTION

In life generally and in engineering especially, finding the optimum results is the target, and it is the goal in almost every application, particularly in problem-solving designs where it is attempted to reach the best value. For instance, minimizing energy consumption and cost or maximizing the performance, profit, and efficiency. In fact, there are always limits to time, resources, and money. For that reason, optimization is very essential to be applied in reality [1] [2]. Therefore, the appropriate utilization of available assets of any kind requires a paradigm change in logical thinking and designing invention. The mathematical optimization started with traditional approaches, for instance, linear programming, sequential quadratic programming, Newton-Raphson, interior-point methods, fractional programming, and Lagrange duality. Subsequently, modern approaches were invented that are mainly going to be evolutionary or bioinspired. Some examples of modern approaches contain evolutionary algorithms, swarm intelligence (SI), artificial neural networks (ANNs), cellular signalling pathways that are mainly classified as heuristic and metaheuristic algorithms. For instance, genetic algorithms (GA) and SI are being used in many applications [3]. Nevertheless, the logistics area has different direct and indirect applications that aim to optimize target solutions in a short time relatively, mainly with using modern digital technologies, such as cyber-physical systems and the internet of things (IoT) that are involved in the newly developed models and these applications gain ground in industrial transformation rapidly in the last few years [4]. Alongside Industry 4.0, other technological-founded industrial processes that aim to improve the industrial process are used, for instance, lean operations, six-sigma, circular economy, and other smart manufacturing tools and systems [5]. Those tools and processes are addressed in the context of improving sustainable supply chains, including collaboration, transparency, flexibility, innovation, and capabilities [6].

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Scientific research in the logistics area has complex and multi-objective cases that are defined as NP-hardness (non-deterministic polynomial-time hardness). These cases are very hard or even impossible to be solved in the conventional methods, i.e., the optimization of vehicle routing problems [7], such as in the cyber-physical systems for waste collection [8] since it has multi variables come from measurements and predictions, and in the multi-objective optimization of city logistics [9], especially when it uses the multi-echelon system. Heuristic and metaheuristic algorithms (modern algorithms) are getting more widely used to reach the best optimization results in the shortest time. Furthermore, hybrid algorithms that combine more than one type are also used for the same purposes since they might achieve better results. However, scientific research is a tower that is being built with the continual efforts of researchers. A significant section of it is to analyse the previous work, efforts, and steps that have been done to contribute effectively to the following research steps. This paper presents an analytical review about the modern algorithms that are used in the logistics area focusing on the heuristic and metaheuristic ones to make its accelerated progress clearer, especially in the industry 4.0 developments that are being spread.

In the following chapter, the used methodology in this paper is described. The third chapter shows an illustrative analysis of the performed search from different perspectives. Within the fourth chapter, the search content is analysed and discussed. The last chapter contains a summary of this work and its conclusion.

2. USED ANALYTICAL REVIEW METHODOLOGY

The used methodology of this analytical review includes the following steps [10]:

- Define the search term (keywords) to use.
- Select which sources to use for the literature search, like Google Scholar, Web of Science, Science Direct, or Scopus.
- Define and characterize the resulted articles depending on the main topic.
- Analyse the chosen articles by reading the abstracts and describe the main achieved scientific results.
- Summarize the main points of the found analysis results and gaps.

The used keywords in this search are “optimization algorithms” as a title, “*heuristic” as a topic, and “logistics” as a topic. The entire search was done within the Web of Science database. Initially, 50 articles were identified. This list was reduced to 47 articles by selecting journal articles only and in English. This search was conducted in mid-December 2020; therefore, new articles may have been published since then.

3. ILLUSTRATIVE ANALYSIS

By classifying the reduced articles depending on the Web of Science categories, the first fifteen categories are detected (Figure 1). The classification of these 47 articles shows that most of them come under computer science, operations management, and engineering areas next to other different categories. It reflects the interdisciplinary use of optimization in logistics.

Figure 1. Classification of the selected articles of the first fifteen categories based on the Web of Science database

The resulted data shows that the modern algorithms in the logistics area have been researched over the past 10 years (Figure 2). The first article was published in 2009 [11]. It presented a three-stage logistics network model for minimizing the total costs to reverse logistics shipping cost and fixed opening cost of the disassembly centres and processing centres as a mathematical model of the remanufacturing system. The number of articles that were published in the last three years (from 2018 until now) is 30 articles that equal more than 63%; this indicates the importance and scientific potential of the research that has been developing rapidly. Although the year 2020 is not the maximum number, it should be considered that the 2020 year has not been finished depending on the conducted search date.

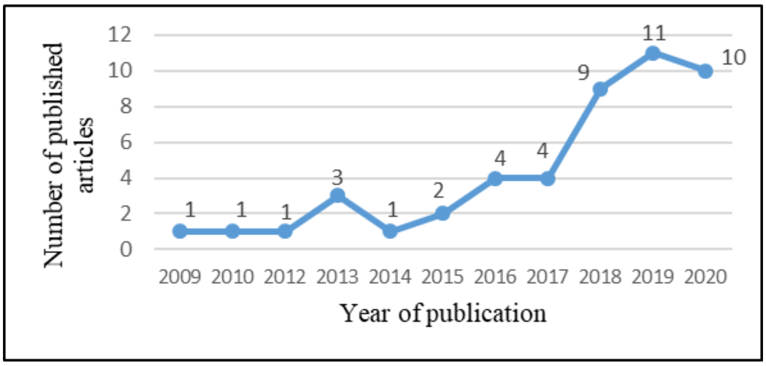

Figure 2. The number of articles by year of publication

The following step is to analyse the resulted articles from a scientific impact point of view. The usual way to evaluate them in this manner is the citation. The five most cited articles within the analysed search results with their citations appear in Figure 3. The first article was cited 137 times as the most significant number of citations among the chosen articles.

Its title is “Imperialist competitive algorithm combined with chaos for global optimization” [12] in 2012. It presented a new chaotic improved imperialist competitive algorithm (CICA). Moreover, a comparison with other ICA-based methods was conducted for the benchmark functions and showed the superiority of the CICA comparing the other ones.

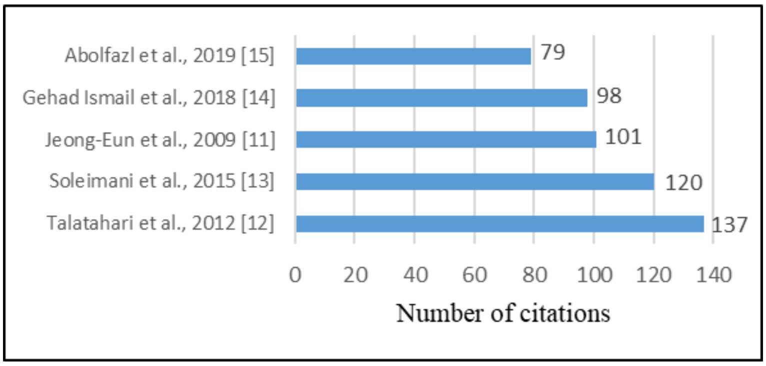

Figure 3. The five most cited articles based on our search in the Web of Science database

In the following phase, the 47 articles' content was analysed. The first step was to read the abstracts. The articles' research was classified and had a more in-depth analysis to reach coherent and direct outcomes.

4. Content analysis and discussion

The articles introduce a wide range of areas and approaches to analyse, solve, and optimize the solutions for several problems in different domains. The modern optimization algorithms were used effectively to reach the desired results.

Shoja et al. [16] presented a hybrid algorithm of the genetic algorithm and particle swarm optimization algorithm for supply chain network design problem with the possibility of direct shipment, and the used algorithm showed superior results. Masood et al. [17] worked on a two-stage heuristic algorithm to enable a cost-efficient delivery for optimizing the material supply to mixed-model assembly lines that contribute to the overall production cost efficiency with reasonable solutions. Another study [18] used a genetic algorithm to optimize service selection and to schedule load balancing (SOSL). Also, an upgraded firefly algorithm (UFA) [19] was presented to enhance the performance in solving constrained engineering optimization problems. Bányai et al. [20] presented a mathematical model of just-in-sequence supply and a flower pollination algorithm-based heuristic was used to determine the optimal assignment and schedule for each sequence to minimize the total purchasing cost, which supports improving cost efficiency, and its performance to increase cost-efficiency in just-in-sequence solutions was validated. Inventory control of reverse logistics for shipping electronic commerce was presented [21] based on an improved multi-objective particle swarm algorithm, and it showed effective results. Another work [22] presented an algorithm to minimize the traveling distance of the handling machines when moving the cargo from an inbound truck to an outbound truck. This problem that was discussed is known as the cross-dock door assignment problem (CDAP), and the solution was represented by a modified classical mathematical model.

It is noticed that a few optimization algorithms were used several times within the analysed articles. To mention three of them; the first one, the ant colony optimization algorithm (ACO), used as a hybrid algorithm. In an article in 2018, a hybrid algorithm of the ant colony optimization metaheuristic and the Floyd-Warshall algorithm was used [23] to minimize pickers' travel distance in manual warehouses. In 2016, a hybrid ant colony optimization algorithm was used for a closed-loop location-inventory-routing problem [24]. It considered the quality defect returns and the non-deficit returns in the e-commerce supply chain system in order to minimize the total cost of both forward and reverse logistics networks. The second one is the swarm optimization. In 2019, a heuristic swarm optimization was used [25] in a low-carbon economy perspective, and it was based on the analysis of the needs for optimizing the distribution path of cold chain logistics of agricultural products. This algorithm was improved from a convergence factor, inertia weight, learning factor, and population size. The results showed that the improved algorithm could effectively optimize the distribution path of cold chain logistics of agricultural products. Even the dolphin swarm algorithm has proved its simplicity and effectiveness, but it was falling into local optimization points high-dimensional function optimization problems [26]. Therefore, chaotic mapping was proposed into the dolphin swarm algorithm (DSA), and the chaotic dolphin swarm algorithm (CDSA) was presented to successfully solve high-dimensional function optimization problems. The third one is the genetic algorithm that was also used in hybrid systems. A study in 2019 [27] provided a comparative analysis of hybrid optimization intelligence models that combined different metaheuristic algorithms like genetic algorithm, particle swarm optimization, shuffled frog leaping algorithm, and imperialist competitive algorithm. In another research [28], a three-stage supply chain network problem including suppliers, plants, distribution centres (DCs), and customers were investigated. This problem as it is multi-echelon supply chain networks, it is considered an NP-hard problem, and a metaheuristic based on genetic algorithm and invasive weed optimization was designed to find the problem solution. The results showed high efficiency by that proposed approach.

5. CONCLUSIONS

This paper presented an analytical review on modern optimization algorithms in the logistics area. The illustrative and content analysis showed accelerated progress in using the heuristic and metaheuristic algorithms for finding the optimum solution within various applications. It also showed the strong presence of the hybrid algorithms recently that are providing very efficient results. This study states the importance of hybrid optimization algorithms that contain heuristic/metaheuristic approaches and emphasizes on its essential role in optimizing the solutions.

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