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Advanced Optimizations Techniques for Electrical Engineering Applications

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Swati Gade*

Sandip Institute of Engineering and Management, Nashik, India

***Corresponding Author:** Swati Gade, Sandip Institute of Engineering and Management, Nashik, India.

Abstract

The performance, utilization, reliability, and cost of the system are all improved when optimization techniques are used to solve engineering problems. Researchers have used a number of traditional optimization techniques like geometric programming, nonlinear programming, sequential programming, dynamic programming, etc to solve these problems. Traditional optimization techniques have been effective in many real-world problems, but they have some drawbacks that are primarily caused by the search algorithms they have built into them. The researchers have developed a number of advanced optimization algorithms commonly referred to as metaheuristics, to overcome the limitations of traditional optimization techniques. All of the probabilistic evolutionary and swarm intelligence-based algorithms used to solve optimization problems require common control parameters like population size, generational number, elite size, etc. along with these need their own algorithm-specific control parameters. The effectiveness of these algorithms is significantly influenced by the proper tuning of the algorithm-specific parameters. When tuning algorithm-specific parameters incorrectly, the result is either an increase in computational effort or the local optimal solution. This article presents a review of the application of algorithm-specific parameterless algorithms in electrical engineering applications. This article is expected to play a major role in guiding research scholars in the application of advanced intelligent optimization techniques.

Keywords: advanced optimization techniques; algorithm-specific parameters; Jaya algorithm; Rao algorithm; teaching-learning-based optimization algorithm

Introduction

Recent trends in manufacturing industries such as globalization of industrialization on a worldwide platform, specific requirements and needs of customers, new products with innovative designs, shapes, and functionality, as well as built-in intelligence and low energy usage, and eco-friendly products, increase the competition between industries, which makes it more difficult for them to survive. It is essential for companies to be innovative and to adapt to changes quickly and effectively, both through conventional means such as cutting costs and time and through the invention of fresh, cutting-edge products and production techniques. All these strategies result in the development of completely integrated, adaptable, and intelligent production systems that heavily rely on cutting-edge modeling and optimization methods. Researchers are motivated to create novel, intelligent optimization techniques to meet the specifications provided by engineers from the industry.

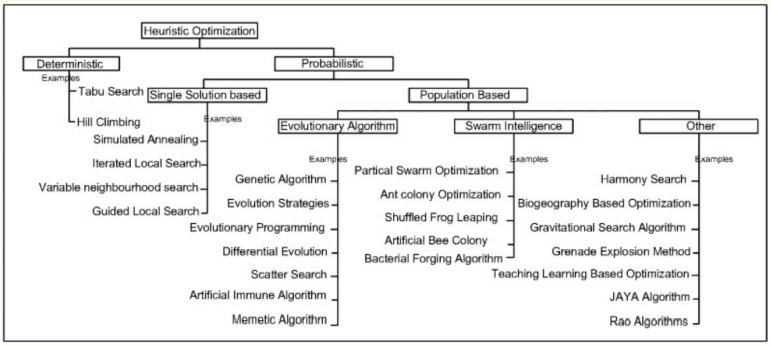

Figure 1: Classification of Optimization Techniques.

Figure 1 shows the classification of optimization techniques. Among all genetic algorithms (GA) is the most commonly used by many researchers. Each of the algorithms is a population-based optimization technique with certain drawbacks such as different parameters known as algorithm-specific parameters are required for the proper working of these optimization techniques. These parameters must be finely tuned in order to find the best solution. The efficiency of the algorithm is affected by changes to its specific parameters. Table 1 shows the various optimization techniques and their algorithm-specific parameters. Modifications and hybridization can tend to make selecting the parameters specific to an algorithm more complex. Therefore, efforts to develop an optimization algorithm free of algorithm-specific parameters must persist.

By introducing algorithm-specific parameter-less techniques like teaching-learning-based optimization (TLBO) [1], the JAYA algorithm [2], and Rao algorithms [3] the difficulty of tuning algorithm-specific parameters is resolved. These algorithms just require standard control parameters, such as population size and the number of generations, and do not need to be tuned.

Algorithm	***Algorithm specific parameter***
Simulated Annealing	Initial annealing temperature and cooling schedule
Genetic Algorithm	Crossover and mutation probabilities, and selection operator
Particle Swarm Optimization	Inertia weight, social and cognitive parameters
Differential Evolution	Crossover probability and differential weight
Artificial Bee Colony	Number of bees (scout, onlooker, and employed) and the limit
Ant Colony Optimization	Pheromone evaporation rate and the reward factor
Harmony Search	Harmony memory consideration rate, pitch adjusting rate, and number of improvisations
Non-Dominated Sorting GA	Crossover probability, mutation probability, and distribution index

Table 1: Algorithms and their specific parameters.

In this article, all these advanced optimization algorithms and their application to engineering are explained in brief. The remaining article is structured as follows: TLBO algorithm and its applications are presented in Section 2. In Section 3 JAYA algorithm with its applications is elaborated. Section 4 covers Rao algorithms and their applications to engineering. The article is concluded with concluding remarks in Section 5.

Teaching Learning-Based Optimization (TLBO) Algorithm

The TLBO algorithm is based on a teacher's impact on the student's performance in the class. The teacher is typically considered a highly knowledgeable individual who imparts knowledge to the students. The performance of students is influenced by a teacher's quality. It is obvious that a good teacher instructs students so they can achieve better marks or grades. Furthermore, students learn from their interactions with one another, which also aids in their performance. This approach was used to construct the TLBO algorithm. TLBO was introduced in 2011 and it is used by many researchers in different fields of engineering. To solve multi-objective problems, it is modified to Elitist TLBO [4], Non-dominated Sorting TLBO [1], hybrid self-evolving algorithm [5], quasi-opposition based TLBO [6], self-adaptive wavelet mutation strategy and fuzzy clustering technique based TLBO [7] has been developed to improve the efficacy of the algorithm. Figure 2 shows the flow chart of the basic TLBO.

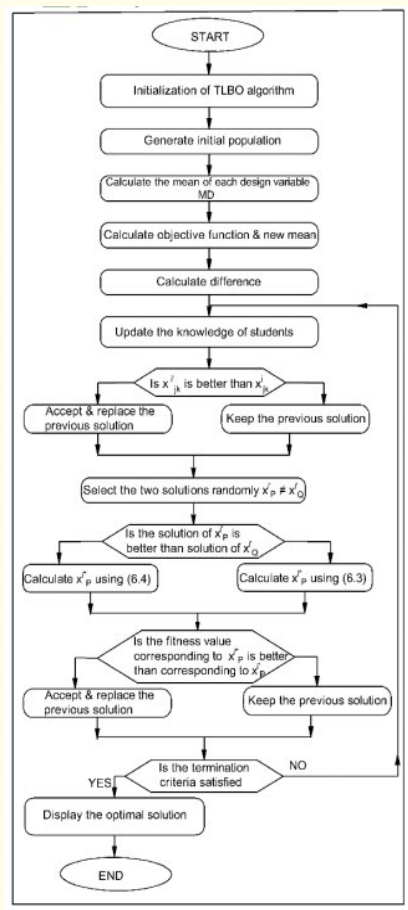

Figure 2: Flow Chart of TLBO Algorithm.

Since the inception of TLBO, it is used in different applications of electrical engineering such as finding the optimal location of various power system equipment like an automatic voltage regulator, FACTS devices, distributed generation, online tap changers, etc [8-11]. It is also implemented for determining optimal VA loading of UPQC [12], optimal energy management, and solving complex multi-objective problems such as unit commitment and economic dispatch schedule problems [13]. It is also used for automatic load frequency control of the multisource power system [14] and reactive power planning [15].

Jaya Algorithm

The main limitation of TLBO is that it works in two phases: the teacher's and the learner's. Therefore, to overcome this another algorithm known as the Jaya algorithm was introduced by V. Rao in 2016. The method was designed with the idea that the solution to a given problem should go toward the optimal solution while avoiding the worst solution. It is also the algorithm-specific parameter-less algorithm. This algorithm is a population-based method, and the selection of the proper population size is particularly important. This problem is overcome by introducing the self-adaptive Jaya algorithm [16]. Similarly, to improve the performance and efficiency of the basic Jaya algorithm few modified versions are introduced such as self-adaptive multi-population JAYA (SAMP-JAYA) [17] and a self-adaptive multi-population elitist JAYA (SAMPE-JAYA) algorithm which is an extension of SAMP-JAYA [18]. Figure 3 shows the flow chart of the basic JAYA algorithm.

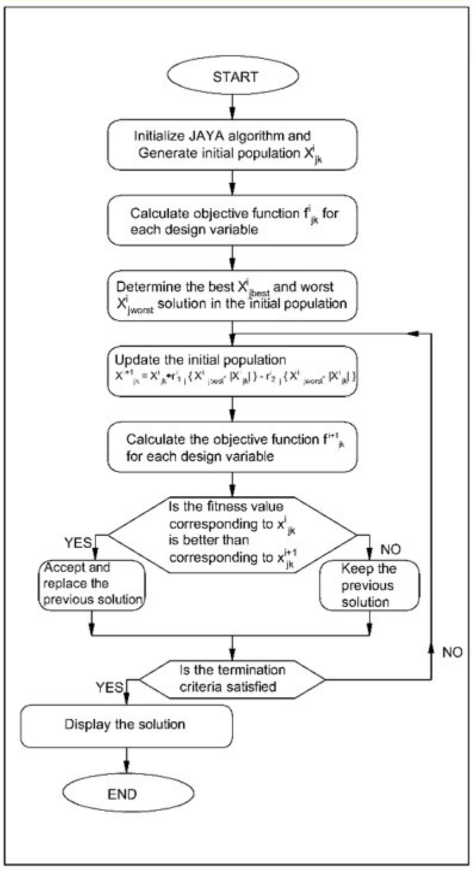

Figure 3: Flow Chart of JAYA Algorithm.

Like TLBO, the JAYA algorithm is also widely used by researchers in electrical engineering applications. It is used to solve economic load dispatch problems, and unit commitment problems [19, 20] It is also used for designing PI and PID controllers for PV-DSTATCOM and automatic generation control applications respectively for obtaining the coefficient of the controllers [21, 22]. It is used to solve OPF problems [23] and implemented to find the optimum VA loading of UPQC [24, 25].

Rao Algorithm

Like the JAYA algorithm in Rao algorithms also the best and worst candidate solutions within the entire population, as well as the random interactions between the candidate solutions, determine the direction of an optimal solution search. Three algorithms were proposed by V. Rao in 2020. Figure 4 shows the flow chart of the Rao algorithms.

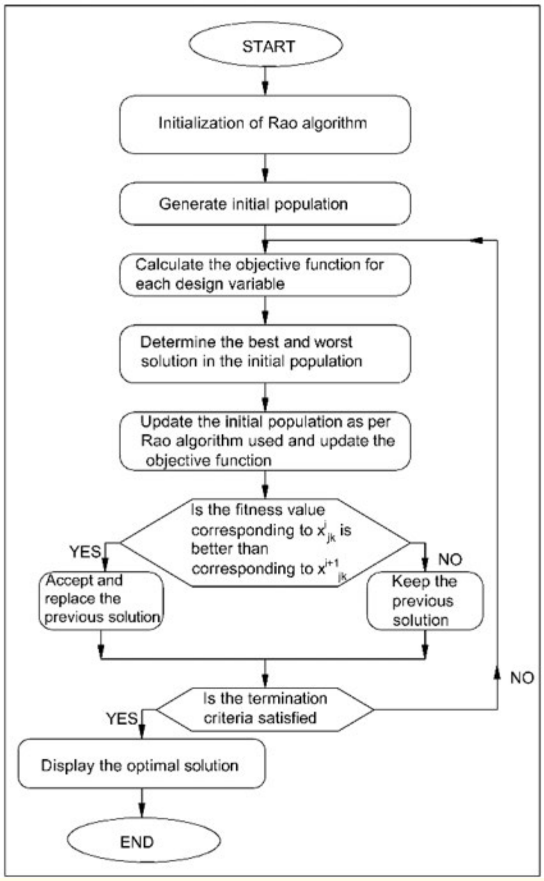

Figure 4: Flow Chart of Rao Algorithm.

From the literature review, it is observed that Rao algorithms are not used by many researchers yet in electrical engineering applications. Rao-1 algorithm is used for parameter estimation of the photovoltaic cell model [26] and optimal VA loading of UPQC [27].

Results and Discussion

From the literature studied for this article, it is observed that the algorithm-specific parameterless concept of these algorithms is one of the attractive features in addition to their simplicity, robustness, and the ability to provide global or near-global optimum solutions in comparatively a smaller number of function evaluations. In some of the electrical engineering applications, researchers have made modifications to these basic algorithms and proved the effectiveness of the modified versions. The limitation of TLBO is, it works in two phases. The JAYA algorithm converges faster than TLBO. On the other hand, the working procedure of all three Rao algorithms is simple and easy to understand and implement.

Conclusion

This article presents a review of the application of advanced intelligent algorithm-specific parameterless algorithms in electrical engineering applications. From the study, it is concluded that these algorithms are more effective and robust than the other optimization algorithms for solving complex electrical engineering problems. However, it is used only in a few applications. There is a vast scope of research in applying all these three algorithms in solving various electrical engineering problems such as the optimal designing of various components of power systems, finding the optimal location of these components, and designing various controllers used in power systems. This paper presents relevant information and may act as a potential source of information for researchers working in the field of power system research.

Conflict of interest

No potential conflict of interest was reported by the author(s).

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