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ANALYSIS OF MODERN TECHNIQUES FOR SOFTWARE OPTIMIZATION

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Abstract: Traditional Methods of optimization have failed to meet up the rapid changing world in the demand of high quality and accuracy in solution delivery. Optimization literally means looking for the best possible or most desired solution to a problem. Optimization techniques are basically classified into three groups, namely; the Traditional Method, Artificial Intelligent Method, and Hybrid Artificial Intelligent technique. In this paper, an attempt is made to review literatures on different modern optimization techniques for application in various disciplines. A general review was made on some of the modern optimization methods such as Genetic Algorithm, Ant colony method, Honey Bee optimization method, and Simulated Annealing optimization.

Keywords: Optimization techniques, Genetic Algorithm, Ant colony, Honey Bee Algorithm, Annealing, Traditional Method, Artificial Intelligent Techniques.

1. Introduction

Most traditional techniques have generally failed to solve large-scale problem, especially those with nonlinear objective functions. One major problem is solving non-differentiable functions with the help of traditional techniques is because they require gradient information which is difficult to solve. These techniques often fail to solve optimization problems that have many local optima. In order to overcome these problems, there is need for the development of more powerful optimization techniques. And these techniques are referred to as modern optimization techniques. Optimization is a technique that is used in every discipline, from engineering design to financial markets, from fashion design technology to mass communication and also applied in our daily activities. Modern optimization techniques have been proposed and also use to solve linear, nonlinear, differential and non-differential optimization problems. In recent

years, various optimizations techniques have been proposed and are in use but some of the most popular optimization techniques such as Genetic algorithm, Simulated Annealing Ant colony method, Honey Bee algorithm will be discussed.

In determining optimal solution for optimal solution for objective functions, we tend to have to have various optimization tools such as linear programming, simplex method, Assignment model, transportation model, CPM and PERT in maximizing profit and minimizing cost in an organization. And the search for optimal solution is ongoing.

2. Related Works

Kanika and Kirti (2015) presented a comparative analysis of different test cases optimization techniques. In their review, they explained different optimization techniques on the basis of their evolution, methodology, performance and applications. Various techniques are being used to test case optimization and in selecting the less indistinguishable test cases while giving the best possible fault coverage. The algorithm may be applied in various domain either using a direct approach or any modified version.

Venter (2018), in his research discussed the standard form of the general non-linear, constrained optimization problem and various techniques applied in solving the resulting optimization problems. The techniques are classified as either local (gradient – based) or globally (non gradient based or evolutionary) algorithms. The review was carried out on some major optimization techniques; rather excluding optimization cases such linear Programming, Convex problems at hand, multi-objective optimization, multidisciplinary optimization etc. Various advantages and disadvantages of the different techniques were highlighted and suggestions made to enable the designer in picking the appropriate technique.

Calvet et al (2020) in their paper reviewed that Heuristic optimization and simulation have been successfully employed in the analysis and enhancement of complex systems and also in processing a myriad of ME/BE 2 related fields. The paper further discusses how challenges and state-of-the-Art methods are combined with optimization, simulation and machine learning could contribute in better addressing them. In the current global market, optimal use of available resources is said to be more important than ever in guaranteeing the economic sustainability in an organization and enterprise. The use of quantitative and computational methods aimed by Managerial and Business Economics (ME/BE) tend to make an assignment of the scared resources owned by the organization.

Tyagi and Tyagi (2015), in their paper “A Comparative Analysis of Different Test Case Optimization Technique” examined various optimization techniques by carrying out comparative analysis based on methodology, evolution, Performance and application. The result of this research is to minimize the time

spent in the testing process in term of test cases used. The various techniques are used for test case optimization to select different test cases while providing the best fault coverage.

Ayalew et al (2019) in their review indicated that comparing different optimization techniques in Power systems planning and operation gave rise to many important decision making problems such as large scale, nonlinear, mixed integer continuous, and non-continuous and non-convex stochastic or robust optimization problems. The use of Artificial Intelligent technique is a far better choice compared to our traditional optimization methods except a hybrid artificial intelligent optimization technique had been used.

3.1 Overview of Optimization Techniques

The main objective of optimization is simply to minimize things that are undesirable such as cost, energy loss, error) or maximize things that are desirable (e.g profit, quality, efficiency). Optimization always involve mathematical problem in various discipline such as engineering, computing etc. Optimization literally means looking for the best possible or most desired solution. Problems associated with optimization are becoming wide and numerous (Ayalew et al 2019).

Optimization techniques are path to attain decision making that will approach goals that have been set in response to given problem. Organizations tend to implement these techniques in order to maximize their profits, minimize their cost, minimize tools, maximize strength and minimize defect e.t.c (Khan *et al* 2015).

3.2 Modern Optimization Techniques

There are different optimization techniques with their application, for diverse troubleshoots or bottlenecks that are been faced in industry and our daily life. We also have best fitted solutions in case of various intermingled issues. We have different types of modern Optimization Technique which include Genetic Algorithm, Ant colony, Honey Bee Algorithm and Simulated Annealing Algorithm (Khan *et al* 2015).).

Optimization and simulation methods are basically used in analyzing complex systems. Optimization methods allow one to obtain optimal or near-optimal solutions for complex decision making whereas simulation method are usually employed when the system is dynamic or the system behaviour is stochastic (Calvet *et al* 2020).

Optimization techniques are path to attain decision making that will approach goals that have been set in response to given problem. The development of optimization techniques began during World War II. So many techniques were developed to satisfy different types of problems like single objective, multi-objective, linear, non-linear, etc.

We always intend to maximize or minimize something which is simply known as the objective function. Organizations are implementing these techniques to maximize their profits, minimize their costs, minimize tool or part travel, maximize strength, minimize defects, etc. The complexity of the problem of interest makes it impossible to search every possible solution or combination, the aim is to find good, feasible solutions in an acceptable timescale. Traditional techniques, find these kind of difficulties for some problems.

Metaheuristics

Metaheuristic algorithms refer to nature-inspired algorithms because their development process is as a result based on some abstraction of nature. The evolution of Nature over millions of years has found perfect solutions to almost all the problems she met. No one manufactures a lock without a key; therefore it is learning process of success of problem-solving from nature and develops naturally-inspired heuristic algorithms. Darwin's evolutionary theory inspired some nature inspired algorithms. And consequently, they are said to be biologically inspired or simply bio-inspired (Khan *et al* 2015). Two basic components of any metaheuristics algorithms are (i) the selection of the best solutions and (ii) randomization. The selection of the best ensures that the solutions will lead to the optimality, whereas randomization ignores local optimal solution and enhances the diversity of the solutions. The effective use of these two components ensures that the global optimality is achievable.

i. Genetic Algorithm (AG)

Genetic Algorithm is simply a class of stochastic search strategies that is modeled as an evolutionary mechanism. It is basically used to optimize non-linear systems with a large number of variables. A new set of points called Population is generated. It evaluates the target function that need to be optimized at some randomly selected points of the definition domain. A Genetic algorithm can still achieve favourable result even in cases where the function has several local minima or maxima (Pandya 2017). According to Srikanth (2020), Genetic Algorithm is a natural computational procedure that has been considerably proven as a solution to optimization problems and it is generally called heuristic search algorithm.

The analysis of genetic algorithm is important even without this practical motivation. And through the course of evolution, the networking pattern of biological neural networks have been created and improved.

The following are steps taken in solving problem related to Genetic Algorithm. They include: Initialization, selection, Reproduction, crossover, mutation and Replacement

The steps are

1. Initialization: GA generally starts with an initial population that is generated randomly to produce a higher quality initial population

2. Selection: Two parent chromosome are selected from a population according to their fitness and the better the fitness the better its chances to be selected.
3. Reproduction: this step select the two chromosomes according to current selection procedures taken to perform cross operation, obtaining one or two children and perhaps applying mutation as well as reinstalling the result back into the population, the least fit of the population will be discarded.
4. Crossover: The crossover probability process tend to crossover the parent to form a new offspring (children).
5. Mutation: The Mutation process is performed immediately after crossover. Mutation is a genetic operator that is used in maintaining genetic diversity from one generation of a population of chromosome to another.
6. Replacement: Using new population generated for further run of algorithm.

In Genetic Algorithm computations, selection, crossover and mutation are the three operators used in computing the genetic composition. It is initiated from a population set with N , and every individual regulates a point (size) whose solution is called chromosome, which indicates list of genes. New generation with highest fitness function with best solution during each cycle is produced from existing population during population doing selection process. Gene values are changed in individuals using random process using mutation whereas the allele of each gene is simply a candidate for mutation and also a function and also the function is determined by mutation. The process keeps on repeating until the optimization criteria is reached (Srikanth 2020).

ii. Ant Colony Method

The Ant colony optimization method is a probabilistic technique that search for optimal path in a graph based on the behaviour of ants seeking path between their colony and their source of food. The basic concept behind this methodology is that it is inspired form the behaviour of ant. It is a nature inspired algorithm. Ants navigate from nest to their food source. They are said to be blind but discover shortest path through pheromone trails. As they move randomly, they deposit pheromone on the path. More pheromone on the path tends to increase the probability of the path being followed. It is a Meta-heuristic optimization method.

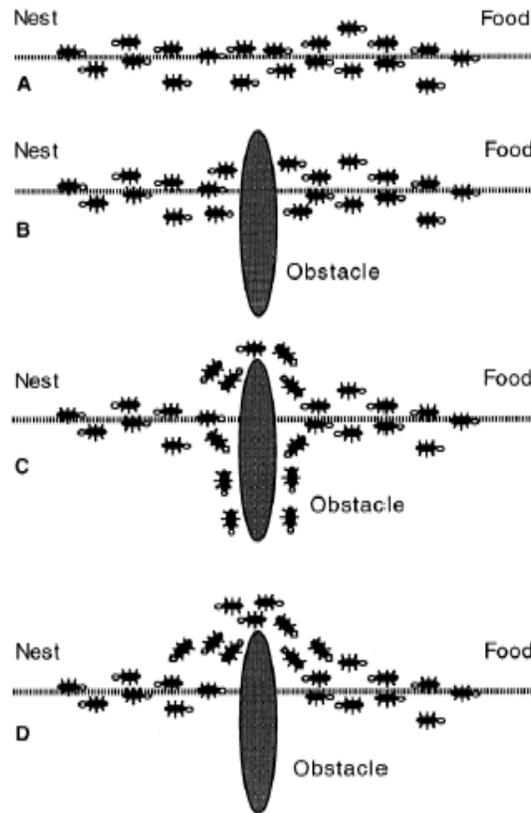


Figure 3.1 how real ant finds the shortest path (Pandya 2017)

Considering the Figure 3.1A Ants conclusively arrive at a decision in which, whether to turn left or right. And since none of them have clue on which is the best choice, they decide to choose randomly. Averagely, half of the ants decide to turn left and the other half turn right. It happens to both ants moving from left to right (those whose name begin with L) and those moving right to left (name begins with a R) Figure 1B and 1C shows that if the ants walk at approximately same speed the number of dashed lines will be proportional to the amount of pheromone the ants deposit on the ground. And since the lower path is shorter than the upper, more ants tend to take that path, and more ants will visit leading to more deposit of Pheromone accumulation faster. Figure D shows that, in as much as the path is sufficiently large for more visiting ants choosing the shorter path.

Ant algorithm is a meta-heuristic search algorithm that have applied to solving NP hard problems. It is biologically inspired from the behaviour of real ant colonies and also how they forage for food in their living environment. One main idea behind this approach is the communication of ants with one another through the concentration of a volatile chemical known as pheromones.

iii. Honey Bee Algorithm

Over the years, studies based on different bee behaviours have been developed in solving complex combination and numeral optimization problem. Behaviours of bees are considered dynamic, in the sense that the social nature of bees because individual insects do not perform all task due to specializations. Generally the social insect colonies tend to behave according to their own division of labour that is related to their morphology. Honey bees are considered as one of the most studied social insect due to its peculiarity among other bees in the social colony. The bee algorithm is a population-based search algorithm that is inspired by natural foraging behaviour of honey bees. The algorithm started with scout bees placed randomly in a search space.

Evaluation of bees is carried out and bees that have the highest fitness are chosen as “selected bees” and also sites visited by these bees for neighbourhood search are chosen. The algorithm then conduct search in the neighbourhood of the selected sites, by assigning more bees to the best e site. The remaining bees making the population are assigned randomly around the search space scouting for new potential solution. The steps are to be repeated until a stopping criterion is reached.

iv. Simulated Annealing Algorithm (SA)

Simulated Annealing Algorithm (SA) is a probabilistic hill-climbing technique that is based on the cooling /annealing process of metals. The algorithm tends to mimic the process of annealing in metal (Zhang & Wu 2012). SA can also be defined as a random search technique for global optimization problems. The annealing process comes up after the heat source has been removed from the molten metal and where temperature starts to decrease. At each level of temperature change, the energy of the metal molecules tends to reduce and the metal becomes rigid. The annealing process really involves strict control of temperature and cooling rate known as annealing schedule. The Simulated Annealing algorithm emulates the annealing of metals. Simulated Annealing (SA) is technique for solving unconstrained and bound-constrained optimization issues. This approach models the physical process of heating a material and slowly lowering its temperature in order to defects and also reducing the system energy. At each iteration of the algorithm, a new point is randomly created. And the distance from the current point to the new point and the extent of the search is based on a probability distribution proportional to the temperature.

Optimization and simulation methods are often used to analyze complex systems or processes.

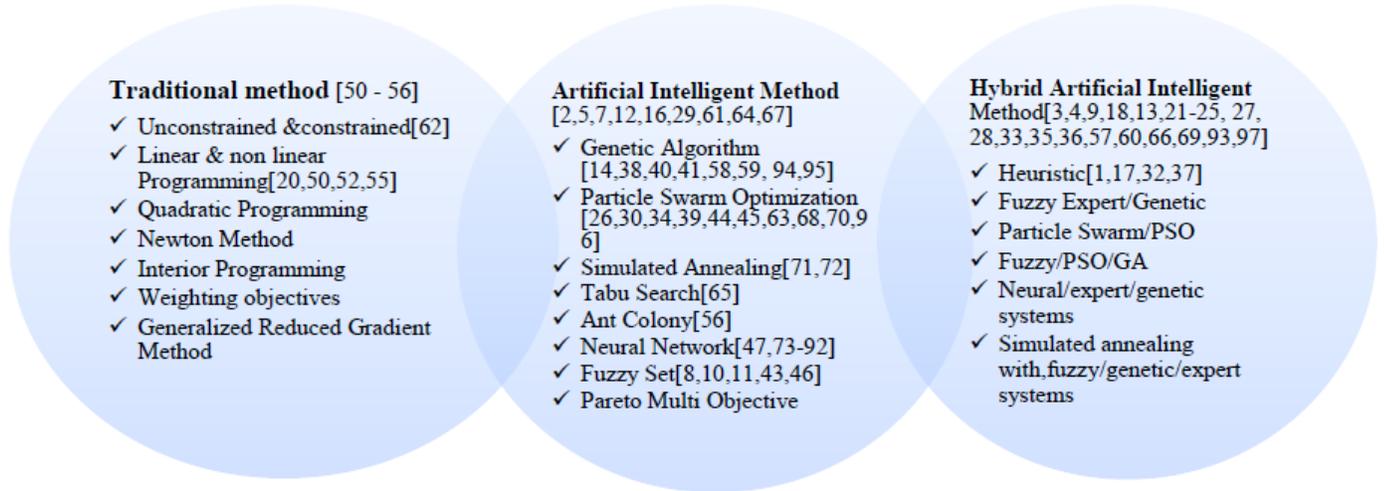


Figure 3.2: Classification of optimization techniques and related works (Ayalew *et al* 2019).

4. Classification of Optimization Techniques

Optimization techniques are basically classified into three groups, namely; the Traditional Method, Artificial Intelligent Method, and Hybrid Artificial Intelligent techniques as shown in Figure 3.2. Computer optimization methods for metal cutting operations can be classified as traditional, modern and intelligent methods.

(a). Traditional Method

The traditional methods are said to be optimality mathematical approach with some algorithms, where problem can be formulated to take advantage of the existing technique that is applicable to large scale power system. They include Unconstrained optimization approaches, Nonlinear programming (NLP), Linear Programming (LP), Quadratic Programming (QP), Generalized Reduced Gradient Method, Newton Method, Network flow programming (NFP), Interior Point (IP) model, Mixed- Integer Programming etc.

(b). Artificial Intelligent Techniques

Artificial Intelligent (AI) techniques have proven themselves to be an effective tool in resolving many power system issues. When joined properly together with conventional mathematical approaches could more be more include Artificial Neural effective. These techniques include Artificial Neural Network (ANN), Fuzzy logic, Intelligent Optimization, Genetic Algorithm, Particle swarm optimization.

(c). Hybrid AI Techniques

Problems associated to power systems can be effectively solved by not just a single AI technique. The better approach is to deal with these complex and real world problems by integrating two or more techniques to overcome the weakness of using just one technique. Combining the strength of two technique generate a hybrid solution. The techniques include Fuzzy neural network system, Fuzzy/neural/expert/genetic systems, Simulated Annealing with fuzzy/genetic/expert systems etc (Ayalew *et al* 2019).

Optimization techniques are applicable on different power system stages such as generation, transmission, distribution and customer’s side for minimizing different problems, and its percentage applicability as shown Fig. 3.3

Application Areas of Optimization Techniques

Application of Optimization techniques is very wide and the various techniques are better applied in specific department or function of organization for efficiency and effectiveness.

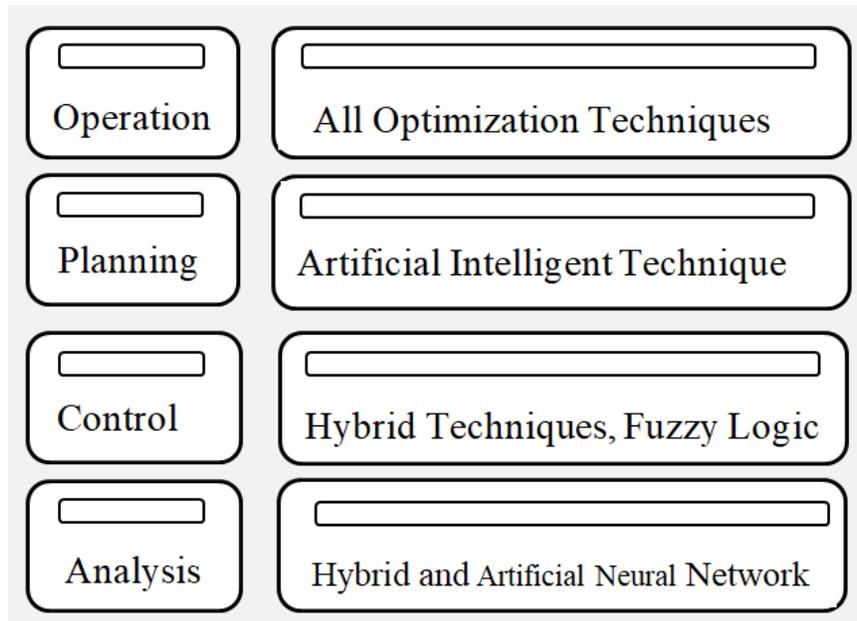


Figure 3.3: Classification of optimization methods with its application (Ayalew *et al* 2019).

Simulated Annealing tend to take a population and applies a reducing random variation to each member of the population whereas Genetic Algorithm takes a population and repeatedly takes two members of the population, mates them so as to produce a new member. A new member could be placed in a new population and the parent may be removed from the original population. Simulated Annealing on the other hand only tracks one solution in the space of possible solutions, and also whether a move to a solution or a stay in the current process according to some probabilities.

Conclusion

This paper tends to discuss the various optimization techniques. A brief description of the various types of methods which include Genetic Algorithm, Ant Colony, Honey Bee and Simulated Annealing. Also various classification of optimization techniques with associated Hybrid technique, Artificial Intelligence technique and Traditional method. The Artificial Intelligence optimization technique has proven itself as an effective too in resolving many issues relating to optimization by properly joining together known optimization methods with other conventional mathematical approaches like artificial neural network.

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