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Optimization algorithms and their applications

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Abstract
In the real world, there are many problems in which it is desirable to optimize one or more objective functions at the same time. These are known as single and multi-objective optimization problems respectively and continuous research is being conducted in this field and nature inspired heuristic optimization methods (also called advanced optimization algorithms) are proving to be better than the classical deterministic methods and thus are widely used. These algorithms have been applied to many engineering optimization problems and proved effective for solving some specific kinds of problems. In this paper, a review of the most popular optimization algorithms used in different problems related to the civil engineering is presented.

Keywords
Optimization algorithms, Civil engineering.

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Contents

1. Introduction

Optimization technique is nothing but the Mathematical optimization or mathematical programming is the selection of a best element with regard to some criterion from some set of available alternatives. Optimization problems of sorts arise in all quantitative disciplines from computer science and engineering to operations research and economics, and the development of solution methods has been of interest in Mathematics for centuries.

The field of data mining increasingly adapts methods and algorithms from advanced matrix computations, graph theory and optimization. In these methods, the data is described using matrix representations and the data mining problem is formulated as an optimization problem with matrix variables. With these, the data mining task becomes a process of minimizing or maximizing a desired objective function of matrix variables.

Nowadays, a rapid growth of computer performance enables and encourages new developments in civil engineering as well as related areas. For instance, the construction industry investigates new designs with minimum cost, minimum CO2 emissions, or embodied energy, among other objectives. Applications of optimization techniques are most exciting, challenging, and of truly large scale when it comes to the problems of civil engineering in terms of both quality and quantity. In order to overcome the difficulties, researchers are interested in advanced optimization techniques. The aim of this special issue is to collect the studies using optimization algorithms in civil engineering problems such as structural engineering, construction management and environmental engineering.

Optimization problem is defined as finding the best solution from the feasible solution in a pool which contains all solutions. In many engineering problems, the optimal solution can be the minimum or maximum value of the objective function of the problem. Sometimes, the optimization problem might have multiple objective functions and multiple solutions. Also, the optimization problems can be classified as size, shape, and topology, discrete, continuous, single or multi-objective optimization. The application of optimization to real word engineering problems is quite recent, mainly due to the complexity of mathematical models, described by non-linear functions and generating a non-convex space of solutions. With the advent of advanced optimization methods, last decades have witnessed a growing application of optimization to a wide range of engineering problems, from automotive to biomedicine, and of course, to civil engineering. Applications of optimization techniques are most exciting, challenging, and of truly large scale when it comes to the problems of civil engineering in terms of both quality and quantity. In order to overcome the difficulties, researchers are interested in advanced optimization techniques.

In the recent literature, researchers have applied the advanced optimization techniques to different purposes. The aim of this paper is to collect the studies using optimization algorithms in different divisions of civil engineering problems in such as structural engineering, construction management, mechanics, transportation and geotechnical engineering. This article consists of two main sections. The first one is the optimization algorithms which have been used to solve civil engineering problems. The other one is the application of the optimization algorithms on different divisions of the civil engineering problem presented. Then, the conclusions and the references are given as last sections.

2. Optimization Algorithms

The same optimization algorithms have been introduced in this section. There are many algorithms; namely Genetic Algorithms (GA), Harmony search (HS), Artificial Bee Colony (ABC), Tabu Search (TS), Teaching– Learning-Based Optimization (TLBO), Particle Swarm Optimization (PSO), Big bang – big crunch (BBBC), Charged System Search (CSS), Cuckoo Search Algorithm (CSA), Ant Colony Optimization (ACO), Jaya, Firefly algorithm (FA), Simulated Annealing (SA), Cultural Algorithm (CA), Differential Evolution (DE), League championship algorithm (LCA), Backtracking Search Algorithm (BSA),Glowworm Swarm Optimization (GSO), Memetic Algorithm (MA), Greedy Randomized Adaptive Search Procedure (GRASP), etc. In addition to these algorithms, similar algorithms derived from these algorithms have been developed by the researchers such as elitist TLBO and intelligent GA. In the multi-objective optimization problem, the name of the existing optimization algorithm may be changed as NDS-GA (non-dominated sorting genetic algorithm). The optimization algorithm and their first original papers are given. Genetic algorithms based on the Darwin's theory about evolution. These algorithms start with a randomly generated initial population which is a set of possible solutions related to the problem. In each generation of the optimization process, the biological operators are used to create next population by the hope that the new population will be better the old one. The main operators used in this algorithm are selection, encoding, crossover and mutations. The new solutions are selected from the current populations according to their value fitness functions.

Harmony search was firstly proposed in the dissertation by Geem[1], then presented in a journal paper by the Geem et al. [1]. It is derived from an artificial phenomenon found in musical performance namely the process of searching for better harmony. Musical performances seek a best state determined by aesthetic estimation, as the optimization algorithms seek a best state determined by objective function evaluation. This algorithm stars an initial harmony memory (solutions sets) and used some parameter such as harmony memory considering rate (HMCR) to improve the next harmony memory. Artificial Bee Colony simulates the intelligent foraging behavior of honey bee swarm. Employed bees, unemployed bees, and scout bees are the type of bee defined in this algorithm. Employed bees search food around the food source and they store the nectar. Unemployed bees choose the source of food with certain probability by following the dances of the employed bees. The unemployed bees turn to the source of the selected food and begin to store nectar as employed bees. Employed bees who consume food sources become scout bees to search for new sources. Tabu Search algorithm explores the search space by a sequence of movies. To escape the local optimum, the certain movies are listed in a memory called forbidden (tabu) search. This algorithm contains some elements: tabu list, neighborhood, aspiration criterion, termination criterion and cost function. Among from these elements, the aspiration criterion is used to determine the best search movie. The new solutions are chosen from the neighborhood of the current solution and the solution which has the minimum cost becomes the new current solution. Teaching–Learning-Based Optimization consists of two phases: Teacher Phase and Learner Phase. In the first phase, the best solution which has the minimum objective function is defined as a teacher. By using the mean solution and the teaching factor, the new solutions are created in the neighborhood of the teacher. If the new solution is better than the old one, the new solution is replaced with the old one. In the learner phase, the solutions obtained from the learner phase are called as student. Randomly select two students are compared with each other. The new solution is created in the neighborhood of the better student. In this way all students are compared to each other. The new solution obtained from the learner phase is replaced the old one if it is better than the old one. So, the solutions are updated in the TLBO algorithm to find global solution. Particle Swarm Optimization is an optimization method based on the using a population of particles to find the optimal solution. In this algorithm, swarm is consisted of particles which are the individuals (feasible solutions),his algorithm does not require derivative information and has an easy implementation in searching the optimal solutions. To find best position (optimal solutions) each particle cooperates with each other by moving according to their velocity.

Big Bang–Big Crunch [2] uses a randomly created initial population as in the other population-based optimization algorithms. Initial population is called Big bang phase in this algorithm. The individuals (candidate solutions) of Big bang phase are dispersed to the search space in a uniform manner. The other phase is the Big Crunch for this algorithm. This phase has a convergence operator to obtain only one output from the feasible inputs. After the implementation of these phases, the new population is created to find optimal solutions. Charged System Search is a population-based optimization method. It is established on the physics laws. Each solution sets are considered as a charged particle. This particle is affected by the electrical fields of the other agents. Each particle has a magnitude of charge and as a result creates an electrical field around its space. The magnitude of the charge is calculated according to the quality of its solution. This algorithm uses a memory to save a number of first charged particles and their values of objective functions. This memory is called as charged memory. The updated charged particles are compared with the old ones, and the better ones are stored in the charged memories. The procedure is repeated by the hope that the optimal solutions will be reached. Cuckoo Search Algorithm [3] is based on the obligate brood parasitic behavior of some cuckoo species in combination with the Levy flight behavior of some birds and fruit flies. There are three rules to implement this algorithm: each cuckoo lay one egg at a time and dump its egg in randomly chosen nest. The egg in a nest represents a solution and cuckoo egg represents a new solution for the process of the optimization problem. Like the other methods, the best solution (best nest) is transferred to the next generations. The number of available host nests is fixed, and the egg laid by a cuckoo is discovered by the host bird with a probability. Ant Colony Optimization [4] mimics the behavior of ants to find shortest paths between their colony and food sources. The main parameters of this algorithm are: ant, pheromone, daemon action, and decentralized control. The pheromones are dropped by the ants traveling for food. The path marked by the high intensity of the trail which is the global memory of the system is chosen by ants. Daemon actions are used to gather global and the decentralized control is used in order to make the algorithm robust and flexible within a dynamic environment.

Jaya [5,6] is a new optimization algorithm. This algorithm starts an initial randomly created population (feasible solution sets). The best and the worst solutions are determined based on the objective function. The new individuals (solution) are generated in the neighborhood of the best solution by avoiding the worst solution. The implementation of this algorithm is so easy. The algorithm strives to become victorious by reaching the best solution and hence it is named as Jaya (a Sanskrit word meaning victory). Firefly algorithm [7] is based on the idealized behavior of the flashing characteristics of fireflies. In nature, the firefly flashes as a signal to affect the others firefly. In FA, this natural phenomenon of firefly is formulated as a meta-heuristic algorithm depending on following three rules: 1-All fireflies are affected by each other without respect to their sex.2- Attractiveness is proportional to its brightness. 3-If there are no brighter fireflies than a particular firefly, it will move randomly in the space. The light absorption coefficient the randomization control factor and the size of population are the main control parameter of this algorithm. Simulated Annealing mimics the random behavior of molecules during an annealing process, which involves slow cooling from a high temperature. SA starts an initial solution called parent. This parent is updated by some manner in the optimization process to set of offspring. Among the offspring the best one can be a candidate to challenge its parent. According to the objective function, if the candidate is better than its parent, the parent is replaced by the candidate. That is, the candidate has a minimum value of objective function. Thus, the best solution is always kept along the optimization process. Cultural Algorithm is inspired by the principle of cultural evolution. A set of traits and generalized description of individual's experiences are used to describe the individuals. There are some parameters such as outlining, dominant belief, acceptance and selection to update the individual for the next generation in CA. For example, through an acceptance function, the experiences of individuals in the population space are used to generate problem solving knowledge that is to be stored in the belief space. Differential Evolution is a parallel direct search. Like the other evolution algorithms, DE uses an initial population. There are two main components in the optimization process of CA: mutation and crossover. Through mutation operator DE generates new parameter vectors by adding the weighted difference between two population vectors to a third vector. Parameter mixing is called as crossover. The feasible solution is generated by two components for the next generation.

League championship algorithm [8] is based on the championship process in a sport league. The terms "league" represents the population, "team" represents the individual, "team formation" represents a solution, "week" represents the iteration, and "playing strength" represents the value of objective function in the process of the optimization problem In LCA, there are six rules to implement the algorithms. Like other population-based algorithms. This algorithm uses an initial process ad update the population in each week to reach the optimal solutions. Backtracking Search Algorithm [9] have five main components to find optimal solutions. These are initialization, selection-I, mutation, crossover and selection-II. In the initialization phase, the size and dimensions of the optimization problem are created. Selection-I phase determines the historical population using the memory. Initial and final form of the trial population is generated by the mutation process and crossover process, respectively. In the Selection-II phase, the best individual is accepted as global solution if its value of objective function is better than the one obtained throughout optimization process. Glowworm Swarm Optimization [10] mimics the behavior of glowworms which are represented by a feasible solution set (individual of population). These are randomly placed in the solution space. Glowworms contain a luminescent quantity called luciferin. The intensity of luciferin determines the value of the objective function of the optimization problem. So, the individual with highest density of luciferin can be defined as the best solution in GSO. In GSO, the glowworms are in interaction with their neighbors and move toward the brighter glowworm using a probabilistic mechanism. According to the value of the objective function, the individuals are updated to create new individuals by the hope that to find global solutions.

3. Application of optimization algorithm For civil engineering problems

In this section, we have explained the two optimization problems on the different divisions of the civil engineering.

A. Optimization in geotechnical problems

Optimization problem was carried out in many fields of geotechnical engineering such as, earth-retaining walls, reinforced concrete shear-walls, and slope stability prediction. The studies presented in recent years using different optimization algorithms for this field is illustrated. Yepes et al[11] presented a parametric study on optimization of earth-retaining walls. They used SA algorithm to optimize the walls from 4 to 10 m in height for different fills and bearing conditions. The design variables of their problem are the geometrical properties of the wall, material types and the reinforcement set-up. The cost function is considered as the objective function. In the structural analysis of the wall overturning, sliding and ground stresses are taken into account as structural limit. Their study estimates the relative importance of factors such as the limitation of kerb deflections and base friction coefficient. At the end of their study, the authors reported the upper bound of 50 kg/m3 of reinforcement in the kerb and 60 kg/m3 for the overall wall. Atabay[12] used the GA to optimize 3D-dimensional beamless reinforced concrete shear-wall systems. In this study, the total material cost function is used as the objective function and constraints of structural optimization problem are taken into account according to the requirements of the reinforcement concrete specification (TS500) and the seismic code of Turkey which is put into effect on 1998. Structural system is analyzed by GENOPT which was developed by the author. By using this program, 13-floored beamless structure was optimized. In the conclusion of the study, the author stated that the GENOPT not only valid for the cost optimization of shear-wall reinforced concrete structure sys but also is valid for the many reinforced concrete structure systems. Pei and Xia [13] presented a study on the design of reinforced cantilever retaining walls using heuristic optimization algorithms which are the genetic algorithm (GA), particle swarm optimization (PSO) and simulated annealing (SA). The constraints of this optimization problem are the design requirements and geometrical constraints. To carry out the optimization process 25 constraints are established, and 9 parameters are selected by the authors. The objective function of the problem is the cost function of the cantilever retaining wall including the cost of concrete and reinforcement per linear meter. This study was previously presented in the International Conference on Structural Computation and Geotechnical Mechanics in 2012. Hosseinzadeh andJoosse [14] reported the design optimization of the retaining walls in narrow trenches. The authors developed an environmentally-friendly method for economic design and optimization of retaining wall. Their study includes both analytical and numerical methods. To investigate the behavior of overlapping passive zones and its impact on the passive soil resistance capacity are the main purpose of this study. In the finite element analysis, the Plaxis programme is preferred by the authors. The author is also carried out the sensitivity analyses with respect to prescribed displacement, interface geometry, soil/wall friction, mesh refinement, boundary conditions, unloading–reloading Poisson's ratio and soil stiffness. At the end of their study, the authors point out that the developed model can be used as reference for reproducing the results for homogeneous soil layering in fully drained conditions. ErolSadoglu [15] examined the design optimization of symmetrical gravity retaining walls. The design of the wall was carried according to the Building Code Requirements for Structural Concrete (ACI 318-99). To reduce the costs of the total wall, the cross-sections area of the wall is selected as an objective function by the author. The problem is solved by developing computer program-based interior point method. The constraint of this optimization problem are design constraints, bending verification constraints, bearing capacity constraint, shear verification constraints, total vertical forces within the middle third of the base constraint, sliding constraint and the overturning constraint. Khajehzadehet al. [16]presented a study on the economic design of retaining wall using particle swarm optimization with passive congregation. The authors developed a computer program in MATLAB using PSOPC. This program is only required to feed the input parameters like soil and material properties and safety factors. They used the cost of the retaining wall as an objective function and taken into account the penalty function method to applying the constraints which are the geotechnical and structural design limits. The cost of the total wall consists of the unit price of concrete, excavation, backfill, formwork, and reinforcement. Das et al. [17] used the elitist non-dominated sorting genetic algorithm (NSGA-II) for the optimum design of retaining wall. They considered both cost and the factor of safety at the same time in the optimization process of the wall and carried out the multi-objective optimization approach. So, they obtained of effective Pareto optimal solutions instead of a single solution. The structural stability is the constraint of the optimization process for this study. The authors obtained both suitable FOS and the corresponding cost the correspfooting dimensions and percentage of reinforcement.

Tonne & Mohite[18] optimized the counterfort retaining wall with relief shelf. In generally, height of 6 m is suitable and economic for the cantilever retaining wall. But it becomes uneconomical above this height. To support more height of earth mass advancement is done in cantilever retaining wall by adding relief shelf in it. In the view of this idea, the authors realized an optimization process. They point out that counterfort retaining wall of heights 10 m, 12 m, and 15 m with relief shelf at h/2 (h: height of stem) gets minimum earth pressure, minimum overturning moment and better stability. Thus, the cost function of the related problem will be reduced. SaritaSingla and Gupta [19]studied on three types of the wall which are cantilever retaining wall, counterfort retaining wall and retaining wall with relieving platforms. They used cost function as an objective function of the optimized problem.

The cost function consists of the volume of concrete and the amount of steel. The constraints of the problem are eccentricity, factor of safety against overturning and sliding, the maximum and minimum bearing pressure, maximum and minimum reinforcement percentage, reinforcement spacing and maximum shear stress. The authors concluded that among all the cases the optimal cost required is least in case of retaining wall with relieving platform. Gandomiet al.[20] presented a study by using some resent optimization techniques: These are the accelerated particle swarm optimization (APSO), firefly algorithm (FA), and cuckoo search (CS). The authors aimed to optimize the cantilever retaining wall based on the ACI 318-05 procedure. The design variables are continuous for wall geometry and discrete for steel reinforcement. The overturning, sliding, and bearing capacity failure modes are the geometrical constraint and the shear and moment failure at the stem, heel, toe, and shear key are the structural design constraint of the optimization problem. Sable and Archana [21] used the "optimtool" in MATLAB to find the minimum cost and weight for concrete retaining walls. The overturning, sliding, and bearing stress are the constraint of the problem. The authors categorized to the design variables in two groups: geometric dimensions of wall cross-section and steel reinforcement. Geometric design variables can be continuous or discrete values. But steel reinforcement variables are discrete. Sheikholeslamiet al.[22] combined the firefly algorithm (FA) and harmony search (HS) technique (IFA–HS) to solve design problems of reinforced concrete retaining walls. In this new technique, the HS operators are integrated into the FA. The authors used the IFA–HS to optimize the reinforced concrete retaining walls. The costs of concrete and steel reinforcement are taken into account as an objective function. Factor of safety, stability, and material properties of the wall are the constraints of the optimization problem carried out by the authors. At the end of the study, the authors concluded that the IFA–HS algorithm was both computationally efficient and capable of generating least–cost retaining wall designs.

Babu & Basha[23] studied on the optimum design of cantilever retaining walls using target reliability approach. To design the wall the overturning, sliding, eccentricity, bearing, shear and moment capacity of toe slab, heel slab, and stem are taken into account the limit parameters of the problem. In this study, the authors gave wall. The authors of this paper stated that if the backfill material is well engineered and if the coefficient of variation is less, then a considerable amount of savings in concrete can be achieved. Babu and Basha presented another study on the optimum design of cantilever sheet pile walls in sandy soils using inverse reliability approach.

Al-Shukur & Al-Rammahi [24] presented a study on the optimum design of semi-gravity retaining wall subjected to static and seismic loads. They used the ANSYS to realize the finite element modeling of the wall–backfill–foundation interaction model. The objective function of the problem is the minimization of the cross-sectional area of the retaining wall. The geometric properties of the wall are selected as design variables. The authors compared the results obtained by using zero-order optimization method in ANSYS with the results obtained by using the optimization techniques GA, PSO, and CSS. Deb andDhar [25] used multi-objective optimization technique to design stone column-improved soft soil. The Non- Dominated Sorting Genetic Algorithm II (NSGA-II) is carried out by the authors. NSGA-II was firstly proposed by the Deb. The authors presented two models named as OMF-I and OMF-II. In OMF-I, there were two objectives; the minimization of maximum settlement over space and the minimization of differential settlement over space. In OMF-II, the objective function is the same with the OMF-II, but there is an additional objective function which is maximization of the average degree of consolidation.

NabeelJasim & Al-Yaqoobi[26] made a study on Optimum Design of Tied Back Retaining Wall. The authors used the GA in the optimtool of Matlab to design the wall. The design variables of this study are the geometric dimensions and the amounts of reinforcement. The bending moment and shear force capacities, and some of the other measures are taken into account the constraint of the problem. At the end of the study, the authors concluded that the increase of the allowable stress of tie steel leads to the decrease of the minimum cost.

B. Optimization in transportation Problems

Transportation becomes possible the communication between and within towns, cities or communities to develop of the civilization. It deals with the planning, designing, constructing, operating of the road, highway, railway, traffic, infrastructures and so on. Sustainability concept considering economic, social and environmental factors together has been also recently implemented in this area. Optimization defined as finding of the optimal solution satisfying some criterion has been also carried out in the transportation. In this subsection, it is presented some research papers which were studied in this engineering field. Putha et al [27]. applied ACO algorithm to solve the oversaturated network traffic signal coordination problem. They identified timing strategies of two example network using the proposed algorithm. One of two models networks examined in was taken from the technical literature while other was an actual traffic network model of the City of Fort Worth traffic signal network. And the obtained results were compared with the previous studies which were employed GA to solve the oversaturated signal coordination problem.

Finally, it was concluded that for the higher number of model executions, ACO become a good alternative to solve the problem of signal coordination for oversaturated traffic networks. Marti et al.[28] described a procedure to obtain the economic cost of pre-stressed concrete precast road bridges. Their algorithm employed a variant of SA as a solver. Optimization problem of double U-shaped cross-section and isosatic spans bridges was described with discrete design variables including the geometry of the beam and the slab, materials in the two elements, as well as active and passive reinforcement. Depending on the results obtained in, it was expressed that different economic scenarios for steel and concrete costs affect the properties of the cost-optimized bridges. Carbonell et al. [29]handled cost minimization problem of reinforced concrete vaults in road construction. Three heuristic optimization methods were implemented to conduct optimization process. One of three methods is SA. For the optimization problem, the cost of the vaults was taken as objective function while 49 discrete design variables were considered. Applying the three optimization algorithms, 10% cost saving was obtained for the vault of 12.40 m of horizontal free span, 3.00 m of vertical height of the lateral walls and 1.00 m of earth cover with respect to its traditional design. Among the applied optimization algorithms, SA outperformed over others in terms of best results.

Martinez et al.[30] described a methodology to determine the most economical tall bridge piers used in deep valley bridge viaducts. For the economical design, three different types of rectangular hollow tall piers were examined for road piers of 90.0m in height. To solve the combinatorial problem, a variant of ACO was carried out. Numerical results obtained by implementing ACO algorithm indicated that the unit price of the internal formwork influenced by the cost of piers, and a type of pier denoted as RTRA90 was found the most economic pier satisfying the design constraints. Garcia-Segura et al.[31] considered the effects of the cost, the safety, and the corrosion initiation time together to optimally design post-tensioned concrete box-girder road bridges. The cross-section geometry, the concrete grade, and the reinforcing and post-tensioning steel of the deck were adopted as design variables. To decrease the computational effort taking more time for the finite-element analysis of the bridge and also to attain an increment of evaluating the conflicting objectives an integrated multi objective HS with artificial neural networks was proposed. The proposed methodology offers trade-off solutions that satisfy comparatively each need for the decision maker. Stevanovic et al.[32] addressed the importance of reducing excessive fuel consumption and vehicular emission on urban streets. To handle this problem traditionally signal timing is optimized. They proposed a tool based on integrating of three previously developed tools called as VISSIM, CMEM, and VISGAOST to optimize signal timings and minimizing fuel consumption and CO2 emission. A 14-intersection network in Park City, Utah was considered as a case study and two major objectives; i) comparison of estimated of the fuel consumption, and ii) minimize vehicular emissions were taken into consideration for the VISGAOST optimization of signal timing.Numerical results demonstrated that the commonly used formula to estimate fuel consumption has not produced a reliable objective function value for the signal timing optimization. Lheeet al.[33]proposed a new approach to predict the owner's cost contingency, which has a significant impact on project financial success and other organizational activities critical, on transportation construction projects. To accomplish this, aim an optimization algorithm based on PSO was used. Evaluation of the PSO-based prediction model was tested on data collected from 492 Florida Department of Transportation projects completed from 2004 to 2006. Its performance was compared with an existing ANN-based approach. The PSO-based prediction model developed in this study has potential for forecasting problems such as estimating cost contingency.

Sabatino et al.[34] proposed a framework to eliminate the effect of structural failure of highway bridges on the economy, society, and the environment. Sustainability and maintenance in the optimization model were treated to provide decision-support framework to decision makers in order to balance conflicting objectives. GA based optimization procedure was used to reach the optimal solution in terms of maintenance interventions. The validity of the proposed approach was tested on an existing highway bridge located in Colorado. The framework is able to aid decision making concerning maintenance actions of highway bridges. Barone et al. addressed deterioration process resulting from multiple mechanical and environmental conditions for civil infrastructures and indicated the proposal of life-cycle optimization techniques supply a rational approach to manage these structure systems. To this end, they developed a novel optimization procedure for life-cycle inspection and maintenance planning of aging structures. Bi-objective optimization procedure defining as minimization the maximum expected annual system failure and expected total cost of inspection and maintenance plans solved by means of GA. Findings obtained demonstrated that the proposed approach is efficient for the optimal life-cycle maintenance scheduling of deteriorating systems. Amjad Arefand Cai[35] stated some technical cumbersome resulting from increasing span of cable-stayed bridge and using traditional materials have not produced satisfactorily results to relieve these technical challenges. They developed a GA-based optimization procedure to cope with this problem. The proposed procedure was able to find the optimal distribution of fiber reinforced polymeric composites for the deck and cable system of cable-stayed bridges. Numerical experiments shown that optimal combination of hybrid glass FRP-concrete deck and carbon FRP-steel cable systems offers 33 and 12% performance improvement on the static and aerodynamic behavior of cable-stayed bridges. Cai and Aref addressed usage of carbon fiber reinforced polymeric (CFRP) materials as an alternative to the traditional materials for long-span cable-stayed bridges. As in, they also implemented a GA-based optimization procedure to find optimal combination of CFRP composites with steel. Unlike which were carried out a multi-objective optimization, single objective being maximization of the critical flutter velocity was adopted in for the optimization process. It was concluded that optimal combination of CFRP and steel caused to maximize the flutter performance of cable-stayed bridges. Chen et al [36] applied IPSO and GA-based algorithm to determine the form-finding analysis of a suspension bridge installation. A form-finding analysis for the main span of the Yingwuzhou Yangtze River Bridge was conducted employing the stated optimization algorithms, and the proposed a novel IPSO-based form-finding method for suspension bridge design and construction overcomes shortcomings of the conventional form-finding methods. Silva et al. [37] addressed the importance of the environmental and operational effects on the structures, which result in some deterioration of structures. They proposed a novel damage detection method based on unsupervised and nonparametric GA to specify the damage in bridges arising from the presence of environmental and operational influences. The GA was also strengthened by a novel concentric hyper sphere algorithm. The capabilities of the method were investigated on the structural damage detection process of two ridges: Z-24 Bridge and Tamar Bridge. Findings showed the robustness and effectiveness of the proposed approach on detecting the damage on bridge system. Liu & Chang [38] presented a GA-based solution procedure to optimize an arterial signal problem. According to the traffic patterns obtained from the end of the optimization procedure, one of two alternatives indicating as either minimizing the total travel time or maximizing the total throughput over the target area for the control objective can be chosen. Experimental analyses carried out an example arterial of four intersections by using the GA-based solution approach demonstrated the effectiveness of it in design of arterial signals, especially under congested, high demand traffic conditions. Hu & Liu proposed offset optimization model based on GA and objective of which was to minimize total delay for the main coordinated direction and to consider the performance of the opposite direction at the same time. The proposed methodology was examined on a main arterial (TH55) in Minessota, and it was able to achieve decreasing the travel delay of coordinated direction significantly without compromising the performance of the opposite approach. Sharma & Kumari conducted a literature survey regarding the utilization of the ACO, BFO, and PSO algorithms in traffic route optimization. ACO was employed in generally traffic controlling and reducing vehicle collisions, optimization of a rail vehicle floor sandwich panel, and vehicle routing design. On the other hands, as comparing the other techniques PSO was able to decrease the computational complexity, and to increase the convergence of the traffic path and more complex path choice models.

Xiao et al.[39] investigated the optimal adjustments of gradation, method of composite modification, and compaction checking in order to enhance the high-temperature performance of the asphalt–rubber mixture. Through these optimal adjustments, they reached improvement considerably on the dynamic stability and relative deformation indices of the asphalt–rubber mixture. The numerical examples demonstrated that the optimal adjustment was for 12 round-trip for the rolling time and 180-190°C for the compaction temperature of the asphalt-rubber mixture. Ghanizadeh[40] developed an optimization model to specify the optimal combination and thickness of different pavement layers that is one of the costly parts of transportation infrastructures. The implementations obtained from the use of proposed optimization model address that application of asphalt treated layer in pavement structure was not cost effective, and also with increasing the strength of subgrade soil, the subbase layer might be taken out from the optimum structure of pavement. Santos & Ferreira programmed an optimization model allowing pavement performance for Life Cycle Cost Analysis (LCCA) to offer the best pavement structure for a road or highway for the designers. OPTIPAV developed tool for this aim was utilized for obtaining LCCA solution of flexible pavements under the serviceability conditions adopted in AASHTO. The applications of the new system indicated that it is satisfactorily alternative tool for the road engineer's toolbox.

4. Conclusion

The potential and effectiveness of some different advanced optimization algorithms are presented in this paper by reporting the works of various researchers in different divisions of civil engineering such as structural engineering, construction management, mechanics, transportation and geotechnical engineering. Approximately 20 optimization algorithms are introduced. It is observed that different optimization algorithms are used for different applications, but one need not claim any particular optimization algorithm as the "best" algorithm among all the optimization algorithms available in the literature. In fact, there may not be any such 'best' algorithm existing! A particular algorithm may not be the "best" for all types of optimization problems. If any algorithm is found having certain limitations, then the efforts of the researchers should be to find the ways to overcome the limitations and to further strengthen the algorithm. Researchers are encouraged to make improvements to the existing optimization algorithms and/or to develop new optimization algorithms. Due to the length limitation of the text, other important works were not included in this selection. Anyway, it is remarkable the growing application of optimization to the resolution of real problems.

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