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Research Article

Genetic Algorithm: Optimization Strategy and Applications in Design

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Abstract

Genetic algorithm is a population-based heuristic search and optimization technique that mimics the process of natural evolution. The optimization strategy followed in the genetic algorithm technique along with its applications related to design in various areas is presented in this paper. The study concluded that Genetic algorithm technique can be used quite effectively to solve a variety of optimization problems in different domains that are not handled easily using other conventional optimization methods. Moreover, it works on population rather than single points and GA operators help to create new population in very next iteration which is better than its parent population, thus the offsprings will guarantee better population and solution will converge in much less time in comparison to conventional techniques.

Keywords: *Genetic algorithm, Optimization Strategy, GA Operators, Optimization.*

1. Introduction

Solving engineering problems can be quite complex antedious process if a large number of design parameters and constraints are involved. Recent advances in the field of technology have led to high computing speed of electronic devices, thereby, the use of optimization algorithms have increased manifold in various engineering design activities. Genetic algorithm is one of efficient optimization method based on the idea of natural selection and genetics [1,2]. The procedure systematically evolves a population of candidate solutions with the desired objective of finding the best solution by using evolutionary computational processes inspired by genetic variation and natural selection[17].

The paper focuses on the optimization strategy followed in the genetic algorithm technique along with review of work done by various researches for solving the optimization problems using GA in different design areas.

Genetic algorithms are search algorithms based on mechanics of natural selection and natural genetics [1,2]. It is based on survival of the fittest principle among string structures with a structured yet randomized information exchange to form a search algorithm. The characteristics of GA i.e. population size (size of search conducted) and number of tests (number of times the optimization process is repeated to ensure that the optimum is being achieved) are set by the user [3].

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Depending upon the population size and number of iterations to be performed, computation time to reach optimal solution varies. Increasing the population size increases the resolution of the search process on the cost of computation time and tolerable error, thus led to increase in capability of the GA to find the optimal solution.

The methodology followed in GA is presented in the form of flow diagram as shown in Fig. 1.

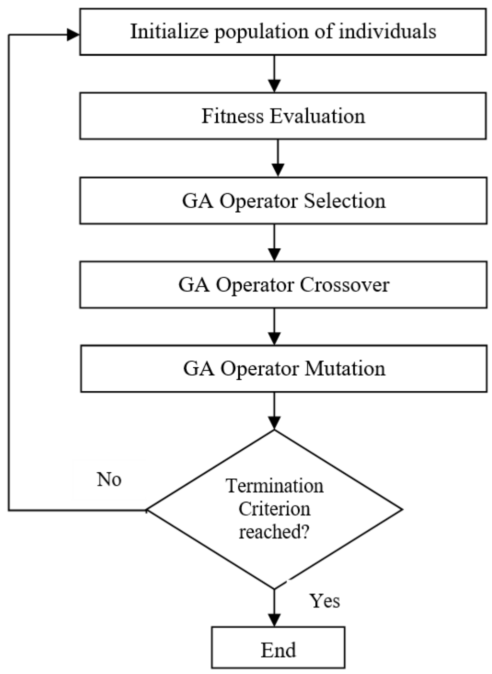

Fig.1. Steps in GA methodology

3. Operators in Genetic Algorithm

Following three GA operators are applied on the population for generating improved solution:

(1) Reproduction
(2) Crossover
(3) Mutation

Reproduction

The purpose of this operator is to select good parent strings from the existing set of population to create mating pool. The offsprings thus produced using those good parent chromosomes would have better features of its parent strings and have more likelihood of survival. Multiple copies of the strings that have above average fitness would be selected from the existing population to create mating pool.

Crossover

In crossover or recombination operation, information is exchanged among the strings present in the mating pool to create new strings. The selection site is selected randomly and strings on one side of the site are interchanged. Effect of crossover can be unfavorable or beneficial. Thus, to preserve some of the good strings in the mating pool, all the strings usually don't participate in crossover operation.

Mutation

While the rationale behind the crossover operator is to generate new strings/population of superior fitness by making significant change in a string's make up, however, to search in the neighborhood of current solution, mutation operator is used sparingly. A new solution is created in the neighborhood of existing solution by making a local change in the string.

4. Application of GA in optimization

Y. Deng *et al*. [4] applied genetic algorithm to solve symmetric travelling salesman problem, the objective of which was to minimize the cost of the tour that involve visiting 'n' number of cities once only and returning to the home city by a salesperson. Better optimal value of the objective function and lesser error was noticed when proposed improved version of GA was applied on the research problem.

Li Zhang et al. [5] examined flexible job shop scheduling problem, wherein workpiece can be processed on machines with different processing times and resources need to be allocated for task configuration and order constraint. A modified non-dominated sorting genetic algorithm (MNSGA) was proposed for solving multi-objective research problem aiming to minimize the total completion time and maximum energy consumption. The effectiveness of the algorithm was tested by running it for varying number of iterations and the results were also compared with NSGA-II algorithm. MNSGA was found to outperform NSGA-II algorithm, yielding best scheduling scheme every time by achieving the multi-objective optimization of minimize the maximum completion time and energy consumption.

Data mining aims to explore the data for valuable information and plays a pivotal role in data analytics [6,7]. The performance of GA for data mining association rules was investigated by Ting *et al.* [8]. A novel chromosome representation for genetic-fuzzy association rule mining results in attainment of higher convergence speed and better solution quality with GA.

Design optimization of reinforced concrete flat slab buildings was carried out through hybrid genetic algorithm by Sahab *et al*. [9]. Overall cost of reinforcement, concrete and formwork constitute the design objection function while cross-sectional dimensions of columns and thickness of floors including size and number of bars were framed as design variables. Minimum and maximum steel reinforcement ratios, flexural strength and shear capacity were framed as design constraints for the research problem. It was found that the optimal solution can improve significantly and converge at the expense of more fitness evaluations by GA.

Ovidiu BUIGA *et al*. [10] considered the optimal design mass minimization problem of a single-stage helical gear unit, whose every element (gears, shafts, radial seal, tapered roller bearing, the shape of the housing etc.) was subjected to changes during GA optimization process. The objective function of mass minimization was subjected to a total of 45 constraints and two different types of materials were taken for the design problem. In the first case, gears were made of quenched and tempered alloy steel and in second case gear material was case hardened alloy steel. Significant improvement in the results was obtained by applying the GA optimization technique in comparison to traditional design.

Vinay Kumar *et al*. [11] devised a more practical method to solve the problem of roller bearing using genetic algorithm. As GA makes random search in the whole domain, so chances of getting trapped in local maxima or minima are minimal. Population size of 300 along with cross-over probability of 0.5 and mutation probability of 0.15 was used in the adopted method. The method resulted in better performance parameters than those catalogued in standard tables. A quantum jumps in the fatigue life of roller bearings designed using the GA approach was found in comparison to those calculated using the standard values.

A constraint non-linear optimization problem based on genetic algorithms was formulated by B. Rajeswara Rao *et al*. [12] for designing rolling element bearings. Maximum fatigue life was formulated as desired objective and a total of ten design variables were considered. Bearing pitch diameter, the rolling element diameter, number of rolling elements and inner and outer-race groove curvature radii were considered as design parameters along with five constants as leftover constraints. Solution was optimized in two stages. Five constants of constraints were given optimum bounds by optimization runs initially and later all ten design parameters were optimized in final optimization run performed by applying GA technique. Better roller fatigue life was observed using GA as compared to those listed in standard catalogues.

Genetic algorithm method was selected for optimization of fixture design by A.H. Nalbandh *et al*. [13]. Fixtures are employed to locate, hold and support workpieces in manufacturing operations such as machining, inspection, and assembly. Fixture design process and fixture design technique with conventional methods didn't yield satisfactory results. So, genetic algorithm technique of optimization was applied for fixture design optimization and integration of the technique was done in terms of fixture layout, clamping position and part deformation. Application of GA for this specific problem has resulted in generation of much better design as compared to conventional methods.

Rajiv Gupta [14] successfully applied genetic algorithm technique for the design of water tank and construction cost for a given volume of water tank. The dimensions of the tank and other corresponding design parameters which might affect construction cost like grade of concrete, main reinforcement bar diameter, main reinforcement bar spacing were considered while formulating the design problem. GA proved to be an efficient search algorithm to optimize design and cost of water tanks. The results obtained using Genetic algorithm show close convergence with the actual global minimum values. It was concluded that by choosing a proper ratio of radius to height, the cost can be reduced by 20%.

M. Bidabadi *et al*. [15] presented new methods, using genetic algorithms, to find the optimal design parameters of a spiral heat exchanger within allowable pressure drops. The method aims to identify optimal points from thermodynamic as well as economical point of view. The method has resulted in higher heat transfer coefficient and lower total cost, thereby leading to conclude the superiority of GA over basic design method. An increment of 13% in optimized heat transfer coefficient and 50% reduction of total cost were achieved using GA compared to the basic designs.

A numerical optimization of the suction valve of a large reciprocating compressor was carried out by J. Prins *et al*. [16]. The optimization was performed by using dual combination of a compressor simulation program and a genetic optimization algorithm. The compressor simulation program was used to solve the mass and energy conservation laws for the suction chamber, cylinder and discharge chamber. A set of optimal designs were generated by assigning different combinations of weight factors to the volumetric efficiency, the isentropic efficiency and the impact velocity of the valve. It was concluded form the study that GA is an effective design tool and is especially useful when a considerable number of parameters is involved.

Conclusion

Genetic algorithms can be applied to complex/constrained optimization problems with ease. Genetic algorithms are very effective techniques of quickly finding a reasonable solution to a complex problem. Since GA is random search algorithm, so chances of trapping in a local minima are nil/absent unlike other optimization algorithms. Three GA operators namely selection, crossover and mutation guarantee to produce better result at each and every stage of the solution as iterations are being performed. Thus, superiority of GA over conventional optimization techniques makes it quite suitable to be applied to a variety of design optimization problems belonging to different domains. Computation time however depends upon the population size and number of iterations to run along with accepted level of accuracy.

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