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A novel Clustering based Genetic Algorithm for route optimization

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ABSTRACT

Genetic Algorithm (GA), a random universal evolutionary search technique that imitates the principle of biological evolution has been applied in solving various problems in different fields of human endeavor. Despite it strength and wide range of applications, optimal solution may not be feasible in situations where reproduction processes which involve chromosomes selection for mating and regeneration are not properly done. In addition, difficulty is often encountered when there are significant differences in the fitness values of chromosomes while using probabilistic based selection approach.

In this work, clustering based GA with polygamy and dynamic population control mechanism have been proposed. Fitness value obtained from chromosomes in each generation were clustered into two-non-overlapping clusters. The surviving chromosomes in the selected cluster were subjected to polygamy crossover mating process while the population of the offsprings which would form the next generation were subjected to dynamic population control mechanisms. The process was repeated until convergence to global solution was achieved or number of generation elapsed. The proposed algorithm has been applied to route optimization problem. Results obtained showed that the proposed algorithm outperforms some of the existing techniques. Furthermore, the proposed algorithm converged to global solution within few iterations (generations) thus favoring its acceptability for online-realtime applications. It was also observed that the introduction of clustering based selection algorithm guaranteed the selection of cluster with the optimal solution in every generation. In addition, the introduction of dynamic population control with polygamy selection processes enabled fast convergence to optimal solution and diversity in the population respectively.

1. Introduction

Genetic Algorithm (GA) is a random universal search technique that imitates the principle of natural biological evolution [1–8]. John Holland pioneered the examination of the dynamics of GAs and the formulation of initial associated theories, thus leading to innovation and growth of GAs in the 1960s [7–9]. In accordance with Darwin's evolution process shown in Fig. 1, GA operates on the principle of survival of the fittest in a population of possible solutions to generate an approximate better or best solution. At each generation, a new set of solution is generated by selecting likely solutions (individuals) with respect to its fitness value within the problem area [7–9]. This is achieved by the application of reproduction operators borrowed from natural genetics. The result of this process is the evolution of populations of offspring that are more adapted to their environment than their parents and are better off in terms of performance[10–12,15]. A probabilistic rule is used by GA to guide its search and selection process thereby reducing the risk of convergence to local solution. In addition, this allows for exploration of most promising areas in search space. This is achieved by considering numerous points in the search space simultaneously, thus, favoring the mating of the fitter individuals [15]. Thus, making GA to be an effective and robust search algorithm that allows the quick location of high quality solution areas in a large and complex search space [15,16,20].

GA stands out among other search algorithms and distinguishes itself by working on a population of individuals, each representing a possible solution to a problem. The fitness function evaluation, population solution encoding and decoding, selection, reproduction and convergence are the basic principles of GA [7,8,20,16].

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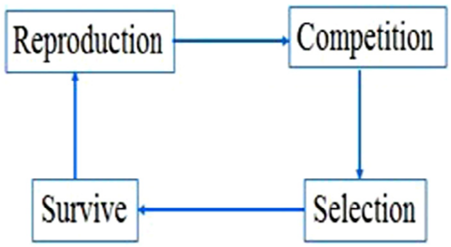

Fig. 1. Darwin's Evolution principle.

Other advantages of GA over other traditional optimization techniques include:

1. The ease of understanding of concepts; robust for usage in noisy environments [7];
2. Ease of running in parallel;
3. Capability of altering or changing the fitness function from iteration to iteration hence facilitating the incorporation of new data if available in the model;
4. Ability to support multi-objective optimization. Furthermore, GA has been shown in various works to sometimes lead to optimal and global solutions [1,2,7,8].

GA has been widely applied to various areas of human endeavor notable among these are: Electronic voltage oscillator designs [1,2], Digital Signal Processing [10,12,13], Welding [14], Communications [17,18], Agriculture [19], Power Generation [20], Finance [21], Robotics [22], Immune System [23], Examination Time Table [24,25], Digital Image Processing [26–28], Time Series Analysis [29], Environmental Planning [30,31], Prediction [32,9], Machining [33,34], Functions optimization [40,41], just to mention but a few. Detailed review of application of GA in power optimization is contained in [11].

The rest of this paper is organized as follows: Review of GA selection process is discussed in Section 2; Mathematical derivation of the proposed methodology is presented in Section 3 while performance analysis and discussions are contained in Section 4. Conclusions and recommendations are presented in the last section of this paper.

2. Review of Genetic Algorithm selection process

In this section, review of GA reproduction process is presented with emphasis on the selection mechanism. Performance comparison table showing the shortcomings and benefits of some of the exiting GA Selection processes is also presented in this section. One of the critical processes in GA reproduction process is the chromosome selection approach. It has been argued that the process determines the success or otherwise of the algorithm since it entails determining and choosing which solutions are good and desirable to be preserved and for reproduction purposes. It ensures that only the fittest survives in each generation while the unfit are discarded within a constant population [3–7]. Numerous GA selection methods exists in literature among which are:

1. Tournament selection
2. Roulette wheel selection
3. Rank selection
4. Steady state selection

- *Roulette wheel selection (RWS) method:* Is one of the most popular GA selection methods and upon which some other selection techniques are based [7–9]. Parents chromosomes are chosen based on their fitness values. In implementing this, the roulette-wheel circumference is marked for each string proportionate to the string's fitness. The roulette-wheel is spun n times and choosing an instance of the string selected by the roulette-wheel pointer each time. The better chromosomes stand a greater chance to be selected since the circumference of the wheel is marked based on a string proportionate to the strings fitness functions. However difficulty is encountered when there is significant difference in the fitness values [7,3–5]. In addition, there is no absolute guarantee that good individuals will be selected though selection is based on fitness value [3].
- *Rank selection methods:* The Rank selection technique was developed to cater for the problem encountered in the Roulette-wheel selection method. In RWS, chromosomes with low fitness values have minimal chances of being selected and large difference in fitness value leads to situation where only the fittest chromosome may be selected. Hence, the ranking selection method was introduced to solve these problems [3,4]. In this approach, individual chromosomes are ranked based on their fitness value and probabilistic approach is then introduced for selection. This ranking approach introduce slow convergence speed and sometimes converge to sub-optimal solution as less fit chromosomes may be preserved from one generation to another.
- *Tournament selection Methods:* In this approach, different tournaments are played among few individuals who are randomly selected from the population. The individual that emerges as the winner of each tournament is chosen for next generation. The tournament size can be changed so as to ease the adjustment of the selection pressure. However, chances abound for selection of weak individuals when the tournament size is large [3,5,4].
- *Steady state selection method:* Steady state selection method involves creation of new offspring by few good chromosomes in each generation. Some bad chromosomes are removed and new offsprings are used to replace the bad ones. Hence, the rest of the population migrates to the next generation without going through selection process.

Summary of the performance evaluation showing strength and weakness of the widely known GA selection processes are presented in Table 1.

3. Development of Clustering based Genetic Algorithm with polygamy reproduction and population control technique

In overcoming the aforementioned shortcomings in the existing GA reproduction processes presented in Table 1, this work presents Clustering based Genetic Algorithm (CGA) with polygamy selection and dynamic population control technique.

The main contribution of this paper is in the development of the proposed technique which overcomes the short comings associated with roulette wheel, rank and elitism approach in GA selection process by minimizing the distance between centroid and individual chromosomes in improving the search space instead of the use of probabilistic approach associated with some of the known selection techniques. The introduction of polygamy mating system, dynamic population control and birth control mechanism introduces greater diversity in the population thus offering better solution with fast convergence speed.

Detailed discussions of each of the steps in the proposed CGA are shown in methodology flow diagram in Fig. 2.

1. Parameters settings
   The proposed CGA technique mimics the natural evolution process that experiences increase or decrease in population over