مجلة

كلية التـــراث الجامعة

مجلة علمية محكمة

متعددة التخصصات نصف سنوية

العدد الثاني والثلاثون

12 كانون الثاني 2022

ISSN 2074-5621

رقم الايداع في دار الكتب والوثائق 719 لسنة 2011

مجلة كلية التراث الجامعة معترف بها من قبل وزارة التعليم العالي والبحث العلمي بكتابها المرقم (ب 3059/4) والمؤرخ في (2014/ 4/7)

Review on crossover operators in genetic algorithm and it's applications in different fields

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Abstract

Genetic algorithm is considered common one as a tool for solving optimization problems in which the performance of it based on finding best solution that's mean production of new individuals in which the process of crossover ensures to gain that. In this paper crossover operators types of genetic algorithm techniques and methodologies are reviewed with details and concern with their applications in some fields are mentioned like in Travelling Salesman Problem and Encryption Problem.

الملخص

تعتبر الخوارزمية الجينية احد الطرق الشائعة لايجاد الحل الامثل للمسائل حيث يعتمد أداءها على إيجاد أفضل حل , وهذا يعني إنتاج أفراد جدد حيث تضمن عملية العبور (التزاوج) الحصول على ذلك. في هذا البحث تم استعراض أنواع عامل العبور في الخوارزمية الجينية بالتفصيل من تقنيات ومنهجيات وتطبيقاتها في بعض المجالات مثل مسالة البائع الجوال ومسائل التشفير .

Keywords: Crossover Operators, Genetic Algorithm, Offspring, Travelling Salesman Problem.

1. Introduction

One of the search algorithms that depend on principles of natural selection and genetics is Genetic algorithms (GA) that presented by J Holland in the 1970's and motivated by the biological evolution of living beings. Another meaning to GA is program of computer based on simulation of the heredity and evolution of living organisms [1, 2]. Since GA is multi-point search techniques, an optimum solution can gain although there are multi modal objective

functions. Essentially, GAs is appropriate to solve problems of type discrete search space. Significantly, GA considered a very influential optimization tool [3].

For implementing GA there's a search space that including set of strings that mean each one of them denote as a candidate solution of problem which named as chromosomes. And the value that result from objective function of it titled as its fitness value. All chromosomes are grouped with their related fitness to define a Population [4]. Basically. The process begin when initial population of randomly created individuals. Three elementary genetic operators that means selection process, crossover and mutation operators have been sequentially employed to every individual with certain probabilities [1, 2]. Crossover the parent genes is considered the elementary strategy employed in GA for generating the best solutions/offspring. Different crossover procedures are constructed to acquire the optimum solution as early as possible in minimum generations. The most effect on the performance of GA is the election of crossover operator. The premature convergence in GA able to avoid by choosing suitable breeding operators [5,6].

In this paper, we discuss types of crossover operators and it's applications in different fields. The following steps are considered for implementing Genetic Algorithm [1, 7]:

Step 1: initially, first population have been generated randomly.

Step 2: fitness for every individual are calculated and save in population that been recently generated.

Step 3: selection operation possibilities of every individual has been determined.

Define selection probabilities for each individual.

Step 4: finally, probabilistically selecting individuals from population are created for yielding offspring via genetic operator.

Step 5: step 2 is repeated till satisfying solution has been gained.

Figure 1 explains the implementation of genetic algorithm [1, 7]:

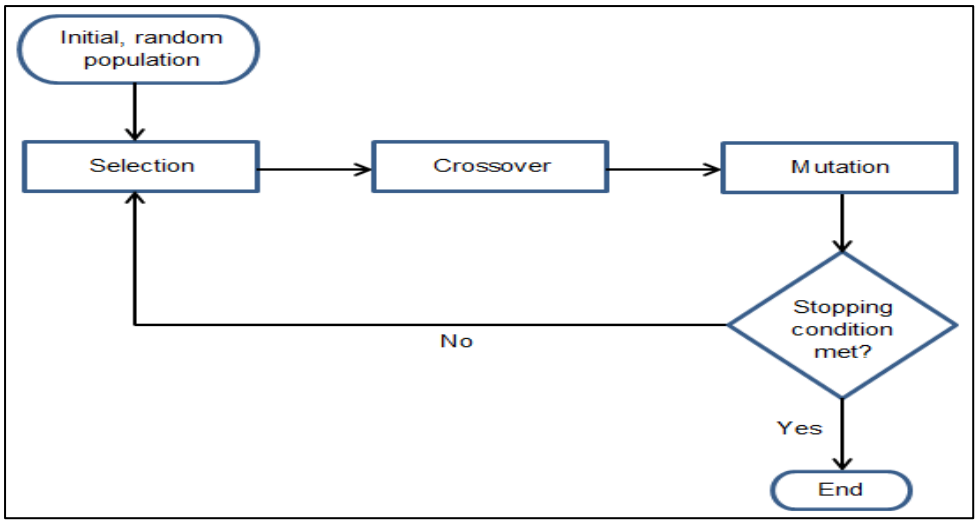

Fig 1: flow chart of GA

This paper is provides an overview on crossover operator with its types that applied in genetic algorithm and its applications in different fields. This paper is organized as: crossover operators are described with details in section 2, then examples of some works that employ these operators are explained in section 3 followed by conclusion in section 4.

2. CROSSOVER OPERATORS

As seen in explained figure 1 crossover one of GA algorithm operations, and in the following the description to the crossover types:

2.1 Single Point Crossover

The division to the chromosomes of both existing parental has been implemented at a randomly defined crossover point when the crossover is achieved. Then the creation operation to the new genotype of the child is beginning when the first parent in which its first part is append with second part of other (second) parent [8]. The selection process to single crossover point on the string of parents' organism is done. The exchange of all data between two parent organisms is apply except that point in either organism string [5]. Enhanced children can be gain by merging good quality parents if proper site is chosen else it harshly hamper string quality, Figure 2 shows the single point crossover (SPC) process [9].

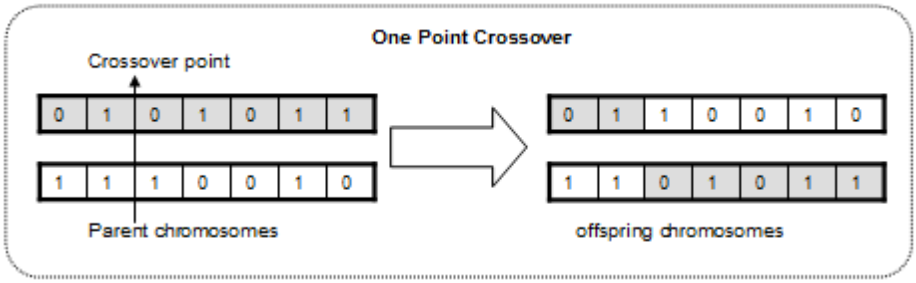

Figure 2. Single point crossover

2.2 N-Point Crossover

This operator type of crossover was first employed by De Jong in 1975 [1]. It contains several cross over sites with the same rules that used in previous type (single point crossover). The importance of crossover sites is 2 in this type of crossover [10]. And in it the division to the genotypes of both parental is applied at two points for creating a new offspring by considering the portions number one and three from the first, and the middle part from the second ancestor [11]. By utilizing this type of crossover poorly performance can be assume since building blocks have been more probable to be disrupted. In another side, two point crossover can make the space of searching problem more methodically [5]. By employing previous type of crossover (single-point) and this one (two-point crossover) operators avoid schema to be disrupted, but search space be smaller when homogeneous population used [8]. The outcome of adding more crossover sites is building blocks disruptions that sometimes case less performance of genetic algorithm [12]. Figure 3 shows the two point crossover process [9].

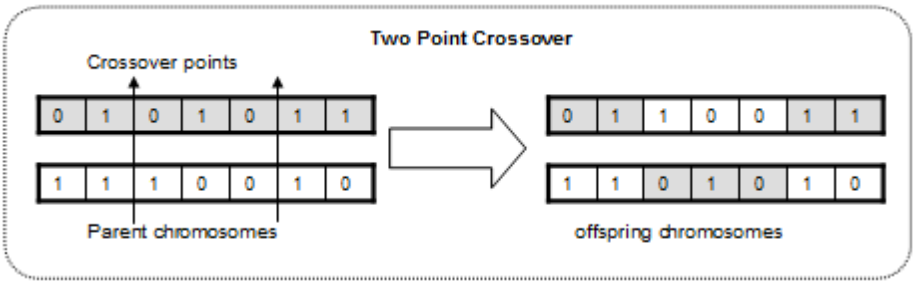

Figure 3. Two point crossover

2.3 UNIFORM CROSSOVER

In this type the bits that exist in both parental are merged in uniform. It accomplishes this process of interchange bits that been exist in the parents to be comprised in the offspring by choosing a uniform random real number *u* (between 0 to 1) [6]. The choosing operation is achieved by it for selecting two parents of crossover. The process of generation to two child offspring of n genes is implemented for electing them from both parents uniformly. The decision operation in which the first child elect *i*th genes from first or second parent is based on random real number [3].

Parent 1: 1 1 1 0 1 0 0 1 0

Parent 2: 1 0 0 0 1 0 1 1 0

Offspring 1: 1 1 0 0 1 0 1 1 0

Offspring 2: 1 0 1 0 1 0 0 1 0

2.4 Half-Uniform Crossover

It is like to previous type (uniform crossover). The difference between them lies in that only half of differing bits between parents will be exchanged [10].

2.5 SHUFFLE CROSSOVER

This type aids in construction of offspring that's mean it independent of crossover point in their parents. This type apply as 1-Point Crossover procedure in further to shuffle. In This operator choosing for crossover of the two parents is accomplished [12]. Initially the genes in the both parents randomly shuffles in similar manner. The creation of two offspring is achieved in a random choose a point as crossover point and after that merging to the both parents is done [9] then the next step to accomplish 1-point crossover , the genes in offspring have been unshuffled in similar manner as they have been shuffled [12].

2.6 Intermediate Crossover

In this type of operator the generation process to offsprings are accomplished by a weighted average that come from parents. The manage process to the Intermediate crossover (IC) is achieved by single parameter *Ratio*:

$$offspring = parent1 + rand * Ratio * (parent2 - parent1)$$

The yielded offsprings considered within the hypercube if *Ratio* is within the range [0,1] delimited by the locations that return to the parents at opposite vertices[9]. *Ratio* can be a scalar or a vector of length number of variables. All offsprings have been lie in the line between the

parents if the *Ratio* is a scalar. Also the children considered to be any point inside the hypercube if *Ratio* is a vector [13].

2.7 Arithmetic Crossover:

In this type of crossover a real-value encoding case is employed. It linearly combines the chromosomes of two parent [8]. Precisely, for crossover the two chromosomes are randomly and the generation of two offspring's which linear mixture of their parents are. A value in randomly that lies in range [0,1] is termed as Alpha. If the parents consist of parent1 and parent2 and parent 1 has enhanced value of fitness, the child has been yielded by the function [11],

offspring =alpha*parent1 + (1-alpha)*parent2

2.8 Three Parent Crossover

In this one type of operator the election procedure of three parents is achieved randomly. Then the comparison is made with every gene that come by the first parent with the equivalent gene of the other parent [10]. The gene is picked for offspring if both genes are the similar else the corresponding gene that come by third parent is considered for the offspring. Generally, it is employed in case of binary encoded chromosomes [7].

2.9 Partially mapped Crossover

This type is named as Partially Matched or Mapped Crossover (PMX), generally is furthermost type of crossover utilized crossover operator in permutation encoded chromosomes. It proposed by Goldberg and Lingle [1]. In this type the association of two chromosomes is done and two crossover locations are elected randomly [13]. The part between the two crossover points of chromosomes offers a matching chosen that undergoes the crossover procedure over position-by-position exchange processes. PMX be likely to respect the absolute positions [14].

2.10 Order Crossover (OX)

It proposed by Davis and also used for chromosomes with permutation encoding [1]. Initially, this type start in case like to PMX by picking two crossover points. But the difference is that in this operator type (order crossover) by implementing sliding motion to fill the left out holes by moving the mapped positions, while in case of PMX point-by-point exchanges is applied, [10]. The coping process to the fragment of permutation components between the crossovers

points from the cut string is implemented directly to the offspring, then Residence them in place as absolute position. OX tends to respect the relative positions [15].

2.11 Cycle Crossover (CX)

This operator of crossover is utilized for chromosomes with permutation encoding. There's some restriction while rearrangement process in cyclic crossover in which every gene either arises from the one parent or the other [13]. When every allele result from one parent jointly with its own position, essential model at back cycle crossover is constructed. The building process of allele's cycle from parent1 begging with the first allele of parent1. Then explore the allele at the identical location in parent2 and go to the location with the similar allele in Parent1 [6]. Insertion operation is done to the allele in the cycle and implement above step again till the destination is gain that's mean reaching for first allele of parent1. Alleles cycle are placed in the first child on the positions they have in the first parent and the rest alleles of that child that get them from second parent along with their position. Yield following cycle from parent2 [16].

2.12 Heuristic Crossover

In this operator type of crossover (HC), heuristic process has been employed for restoration the offspring that be existent in the line in which the two parents have been there, a distance with less value away from parent with the improved fitness value in the trend away from the parent with the poorer value of fitness [2]. The default value of *Ratio* is 1.2. If the two parents have been parents, and enhanced fitness value with parant1, the child has been result from the function [11],

offspring = parent2 + Ratio * (parent1 - parent2)

3. An existing crossover operators in genetic algorithms works:

Some fields that applying crossover operators types are detailed below:

- **Travelling Salesman Problem:**

Authors in [17] present a new operator of crossover termed as sequential constructive crossover (SCX), search operation is achieved on solution space and new chromosomes from old ones are generated. Significantly, crossover is a search process. At beginning, the election process is accomplished in random on pair of parents implemented from the mating pool. Secondly, a random selection to a point named as crossover sit along with their length and the exchange is made to the information that lies after this sit of crossover to the two parent string, thus

producing two new children. And authors in [16] showed a new crossover operator which works as the same as CX, so their suggestion as CX2. Simultaneously it generates both offspring using cycle(s) from parents until last bit. Totally, distance will be minimized for traveling salesman problem. This method is related with path representation, mostly, its natural approach to represent a legal tour. Also in [18] proposed a self-adaptive mechanism termed as adaptive recombination with three sub-populations (ARTS), it explained for managing the crossover operator of a genetic algorithm. Dynamically, in it the crossover can be exchanged between two-point crossover (i.e., the least disruptive crossover), uniform crossover with probability 0.2, and uniform crossover with probability 0.5 (i.e., the most disruptive crossover). In [19], a new methodology for self-adaptions of Steady State Genetic Algorithms (SSGAs) operators has been proposed. Employing this suggestion for improving to solve Traveling Salesman Problem. Authors in [20] proposed a new crossover operator that doing same as PMX, therefore the suggestion is like PMX2. Two random cut points have been selected on parents to forms offspring, the part between cut points, the mapped process for one parent's string is applied onto the other parent's string and the exchange for the rest information is done.

- **Encryption Problem :**
  In this field, authors in [21] proposed Two Way Crossover techniques apply on both sender and recipient end to increase the file security and reliable transmission of data or information in open network. Single point crossover operator is employed on the both level. The election process on parent strings is implemented of single crossover point. New offspring's are created when the exchange process is done on all data beyond that point in the parents. {Sender end crossover A}. Then the same procedure is implemented on receiver end in which the massage has been decrypted (original massage). "Two way crossovers" is the termed to the whole process. Also in [22] showed the using of two point crossover methods. In this technique of operator, the election procedure on two random points is done from the two parents and the exchange process on bits between two points are done to yield the child chromosome. And authors in [23] tried to prepare a technique for applying encryption process on data based on symmetric key. The using of randomness is in two point crossover methods and the creation to the one time symmetric is by mutation. Randomly, the creation to a permutation factor is done and employed to the successive blocks of text for making the algorithm more unpredictable for

the intruder. And in [24] presented how the working of genetic algorithm to provide the optimal keys and the effect of every key in the improving security.

4. Discussion

1- A number of crossover methods can be used with TSP applications, such as PMX, OX, CX2, and other crossover methods. The results of the studies show that CX2 performs better than PMX and OX transitions. It also gets accurate results and is quick to converge.

2- A number of crossover methods can be used with Encryption Problem applications, such as single point crossover and two point crossover. The results of the studies show that the process of choosing the appropriate method to obtain accurate results depends on the chromosome length and the population size.

3- Overall, the process of choosing the crossover method depends on the nature of the issue to be solved as well as on the length of the chromosome and the size of the population.

5. Conclusion

Various types of crossover strategies are used for creating new and enhanced generations in GA in different applications. Major criteria that considered to elect crossover is the encoding type in GA. As explained in previous sections different fields employing these types of crossover by considering their effectiveness to solve a specific problem as Encryption and Travelling salesman problems. Old crossover operators along with additional changes are used by new one.

Acknowledgment

The authors would like to thank “Department of computer science”, “Collage of science”,” Mustansiriyah University (www.uomustansiriyah.edu.iq)”, Baghdad-Iraq for supporting the present work.

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