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A New Approach for Solving N-Queens Problem with Combination of PMX and OX Crossover Operators

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ABSTRACT

The optimization of the complicated computational problems using algorithms based on population is increased, considerably. In this paper, we use Genetic Algorithm (GA) with a new structure to optimize the optimal solutions to solve N-Queens which is one of the combinatorial optimization problems. For increase the efficiency of GA and prevent from premature convergence, it is used crossover operator. So, to keep the primary population and optimal solution in each generation, it is selected the most fitness population. By performing operations, it is created chromosomes with less conflict. In this case, not only we prevent premature convergence, but also keep the population variety in a balanced scale. In this way, not only we prevent from premature convergence, but also keep the variety of population in balanced way. So, more parts of search space will be explored. The experiment results showed that GA has high efficiency to find optimal solution by combining crossover operators.

1.Introduction

In the recent decades, intelligent optimization algorithm which inspired from nature, have been shown good results and success. It can be noted to the methods such as Genetic Algorithm (GA) [1], Ants Colony Optimization (ACO) [2] and Particle Swarm Optimization (PSO) [3]. This algorithm has been used to solve many problems of optimization in different fields [4, 5, 6 and 7].

One of the well-known issues in combinatorial optimization field is N-Queens. The goal of this issue is to arrange N-Queens in an N×N chessboard as none of them take guard to each other. N-Queens problem was firstly suggested by chess player called Max Bezzel [8]. Till then, many mathematicians such as Gauss have been studied on N-Queens. The first solution of 8-queen is provided by Franz Nauck in 1850[8]. He was also the first one who spread 8-queen to N-Queens.

The optimization algorithm based on population (such as GA) has mainly two applications. The first one is that most of these algorithms produce a global optimal reply as optimal solution and the other one is that these algorithms are usually suitable to solve a specific kind of optimization problems (discrete or continuous).

The GA can search very big spaces in an almost shorter time for each solution at the aim of estimating optimization scale than the classic mathematics methods. At the other hand, the available complication increase in combinatorial optimization problems reveals the necessity of using algorithms based on population. These algorithms are a kind of modeling from creatures' natural behavior and in fact, search for optimal solution by simulating their behavior. When a problem has several solutions, it is complicated and there is the possibility of providing several solutions as an optimal solution. So, the main goal of using GA in solving N-Queens problem is to provide a series of non-conflict solutions.

Solving N-Queens problem using GA is done by a series of replies which are optimal solution. By suitable repetition of algorithm, the replies which have most fitness will remain, so, it is suitable to solve N-Queens which have many solutions.

In this paper, by combining crossover operators, the possibility of reaching to the optimal solution is done in a shorter time and the best obtained chromosome of all generation is introduced as the final reply. So, the goal of combining crossover operators is the fitness of target function or in other words the lack of the number of queens' conflict.

We organize the general structure of this paper as follow: in Section 2, the previous works and studies are introduced; in Section 3, GA is represented; in Section 4, the proposed solution is explained; in Section 5, the review and results of the proposed algorithms are presented; and finally in Section 6, conclusion and future works are discussed.

2. Related Works

The most effective algorithm of N-Queens is the algorithm which has found the optimal solution in the least computational time. In the recent years, the researchers have been used different methods to solve N-Queens problem.

F.S. Gharehchopogh et al [9] have been reviewed N-Queens problem using BFS and DFS algorithms. The results indicated that DFS algorithm reaches to the optimal solution in shorter time than BFS algorithm. They also indicate that increasing knots in DFS algorithm is less than BFS and occupied less memory. Researchers [10] have been used Repair and Systematic strategies to solve N-Queens problem. They also have been used Intelligent Heuristic Search Algorithm (IHSA) to solve N-Queens. The goal of providing HISA is to optimize the algorithm operation time to reach non-conflict solution.

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According to their results, IHSA reaches to the optimal solution in less time than Repair Search and Systematic Search algorithms. Reference [8] has been used a unique solution to solve N-Queens problem. In the provided algorithm, to prevent queens' conflict with each other, the location of each queen is reviewed as row, column and diametric **.**The goal of providing this paper is to decrease the computational complexity of N-Queens algorithm. Researchers [11] have been provided a new method based on linear algorithms considering the decrease of program operation time. Researchers [12] have been discussed about N-Queens problem using GPGA (Global Parallel Genetic Algorithm). In their paper, the search to find optimal solution is done based on three operations: Select, Crossover and Mutation. To decrease the time of algorithm operation, their operation is performed as parallel.

3. GA

GA was firstly used as one of the methods based on population by John Holland in 1975 [1]. GA is an efficient optimization method which includes most positive characteristics of random and meta-heuristic methods and is used as an optimized method for combinatorial problems. The first step in GA is to provide the primary population as random or heuristic. Each population member is called chromosome and each chromosome is considered as a reply. During algorithm operation, to find an optimal solution for optimization problem, it must be applied changes on chromosome population. The evolution of chromosomes is done in two stages. In the first stage, some chromosomes are selected among available population based on fitness. They combine to create a new chromosome. The second stage is called mutation in which one or more chromosomes are selected randomly in each repetition. One of the genes of the chromosome are also selected randomly and changed based on a specific mechanism. So, new chromosomes are created. As a result, the obtained replies in each population generation are changed and new generation is created which is more effective to reach an optimal solution.

The obtained replies of GA have a kind of possible nature. It means that once a program operated, the different result from the previous repetition is achieved. In fact, it can be said that GA is a kind of memory random search in which the search process is done around the obtained replies of previous stage randomly. As a result, to reach reliable results, it must be performed repeatedly. One f the capabilities of the GA is avoid from local optimal points. This characteristic is done by GA operators. One of the reasons which make GA popular is that there is no need to use high level and modern mathematical model. In this algorithm, it is usually used evolution ideas and population improvement.

4. The Proposed Algorithm

To find optimal solution of N-Queens problem using GA, a series of possible values are selected as the primary population randomly. Then, by doing evolution process on this population, it can be reach to the optimal solution. In GA, the search to find optimal solution is started by using population and several points in search space. In GA, the most optimization operations are done by crossover operator. To have less number of conflicts in N-Queens problem, it is used the combination of Partial Match Crossover (PMX) [13] and Order Crossover (OX) [14] operators.

4.1. Crossover Operators

After a series of best chromosomes is selected, crossover operator applied with the aim of producing better chromosomes from them. The goal of crossover is to search the space widely and reach to an optimal solution.

4.1.1. PMX

In PMX, two crossover points are selected between first and second parent. Then, the genes are replaced between first and second child. Unsigned genes of first parent are removed if it repeated and the genes of second parent are replaced. In Fig (1) PMX operator method is indicated.

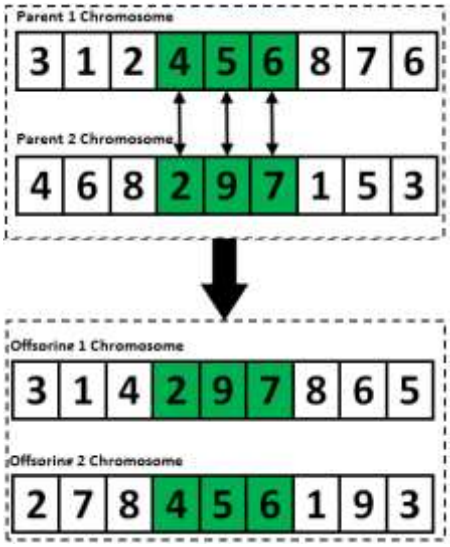

Fig (1): PMX Operator

4.1.2. OX

In OX, it is firstly selected two crossover points from the second parent and the genes are replaced between these two points in the first child. As a result, the marker of the first child remained on the second point. If the first parent includes the genes of the second parent, it is removed. The second crossover point is going to move right on the first parent and if the new gene is available, it will be placed in the first child indicator location and move the indicator forward. If we reach to the last gene of the first child or parent, we return back to the starting point to complete the genes of the first child. In Fig (2), the hierarchical crossover operator is applied on the first parent and the new chromosome of the child produced.

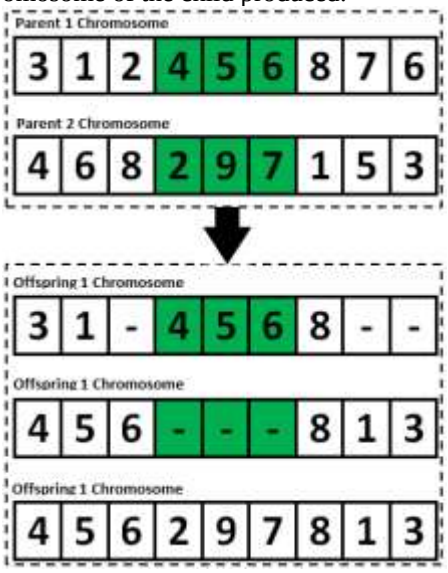

Fig (2): OX Operator

4.1.3. New Combinatorial Crossover Operator

In combinatorial crossover operator, if we want to have better generation than the early one, we must produce chromosomes with high fitness. So, to determine whether the

chromosomes have the less conflict in chess board, we use OX and PMX operators' combination. Moreover, it we want to preserve the best chromosomes of the previous generation, we put them in the worst place of new generation chromosome using the combination of crossover operator. In this method, population with higher fitness will be produced and the best chromosomes replaced by the worst ones. By doing so, the convergence is going to be optimized and the program operation time to find suitable reply will be decreased. Fig (3) indicates the proposed crossover operator on chromosomes.

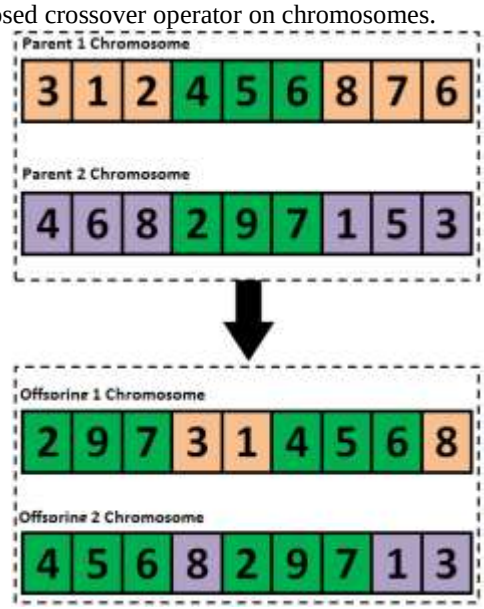

Fig (3): New Combinatorial Crossover Operator

In new combinatorial crossover operator, it is tried that the available values of produced children have the less conflict. As it can be seen in Fig (3), firstly, a point on chromosome is chosen randomly and the parents are cut from that point. Then, by applying local changes, new children are created. For the optimal state of this operator, it is suppose that the cut points are selected from mid-points of chromosome randomly. The new combinatorial crossover operator is used to minimize queens' conflict.

By using GA, we can reach to the non-conflict replies without expanding all faster states in N-Queens space. So, in the proposed algorithm, it is tried to provide better solutions considering the combination of crossover operator and algorithm reaches to the comprehensive optimal solution in lower number of generation. Fig (4) indicates the proposed algorithm.

In the proposed method, to end up algorithm operation, it is used three different methods. In the first method, to end up algorithm operation, it is used fitness function. In this method, after producing each new generation, the fitness scale of the best available chromosomes is measured considering the number of conflicts. If the numbers of conflicts are low the algorithm operation will be stopped. In this method, it can be almost sure about optimal solution after algorithm operation ends up. In the second method, to end up algorithm operation, it can be used the number of generation. In this method, we can limit the number of produced generations to a specified number using algorithm before program operation. So, after producing several specified generation, the algorithm operation is stopped and the best available chromosome of all generation is produced as the optimal solution.

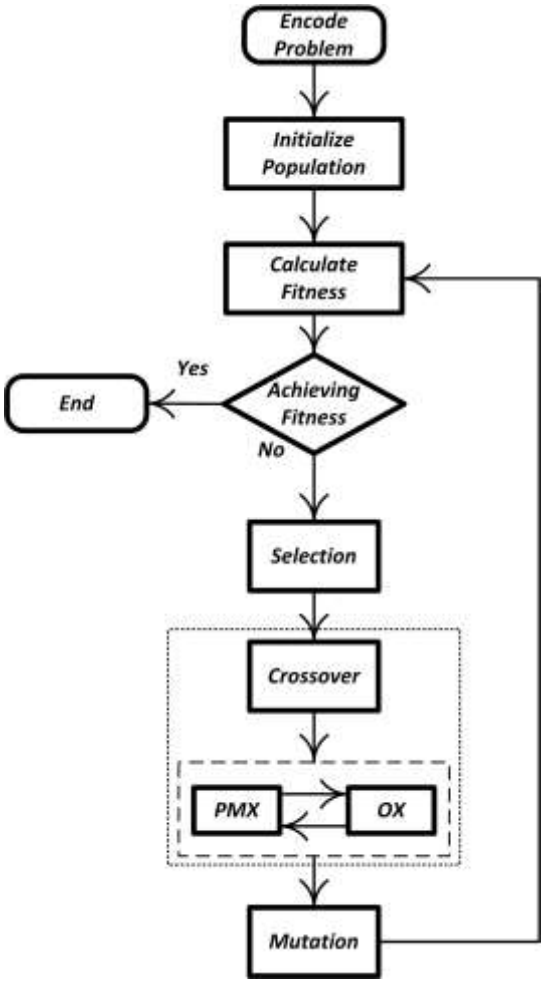

Fig (4): The Proposed Algorithm Flowchart

As a result, in this method, it is possible that either the algorithm doesn't be the optimal solution or the provided solution by algorithm is a suitable reply for N-Queens. In the third method, it is used the combination of criteria of best fitness and the number of generation. In this method, the algorithm is successful to find the optimal solution with higher accuracy and causes that the generation with better fitness is produced. So, this method is effective and efficient to search in big spaces. Quasi code of proposed algorithm to solve N-Queens problem includes below stages.

1. Initialize population
2. Evaluate the fitness of each individual in the population
3. While <terminating condition> do
   - **Select best-ranking individuals to reproduce**
   - **Crossover**
     PMX Operator
     OX operator
   - **Mutation**
4. Evaluate the individual fitness of the offspring
5. Replace worst ranked part of population with offspring
6. End while

Fig (5): Quasi Code of Proposed Algorithm

The program of solving N-Queens using combination of GA operators implemented in C#.NET 2010 programming language environment. In Fig (6), the general view of the program is indicated. As it can be seen, the program provides the best solution in very short computational time and without conflict.

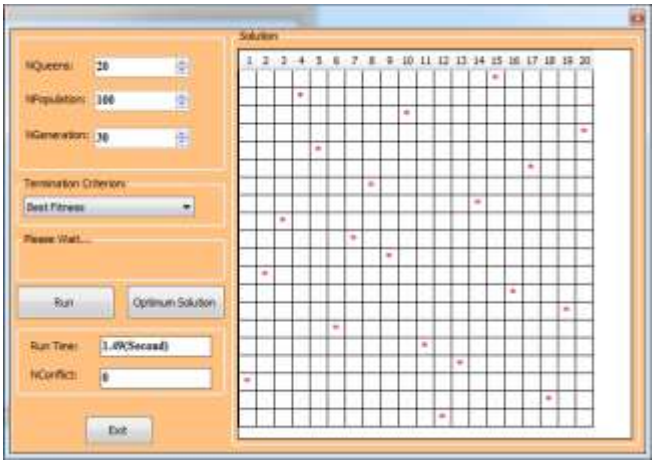

Fig (6): The Program of Solving N-Queens

5. Results and Discussion

In this section, the obtained results are assessed from the provided program operation and the effect of crossover operators' combination in the program is reviewed. The main factor of replies convergence and their acceptability is the combination of suitable operators on problem. So, the algorithm is going to produce accurate and acceptable replies and cause consistency. Crossover operators' combination with the least repetition number of chromosomes which have higher fitness is reviewed and provided as non-conflict solution. In Table (1), the obtained results of GA and Intelligent Heuristic Search Algorithm (IHSA) are represented.

Size N	Time (Sec.)	
	GA	IHSA [10]
16	0.70	11.2
17	0.67	77.2
18	0.90	576

Table (1): Comparing GA with IHSA

As it can be seen in Table (1), the obtained operation time from GA is better than IHSA due to the combination of crossover operators in all cases.

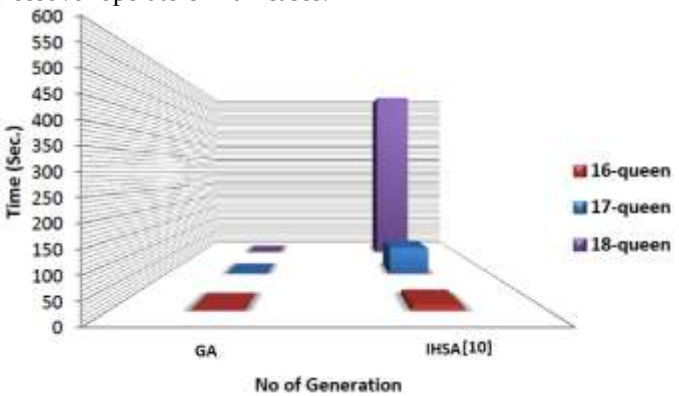

Fig (7): Comparing the Operation Time of GA with IHSA

In Table (2), it is reviewed the computational time of algorithm considering the number of generations. As it can be seen, the algorithm reaches to the optimal solution in shorter time by combining crossover operators even with less generation number.

The new combinatorial crossover operator plays an important role in the number of generations. It means that as the number of generation is decreased, the calculation and program operation time is also decreased. So, in new combinatorial crossover, it is used less generation to decrease computational or calculation time. Consequently, combining crossover operators causes that the number of queen conflicts in chromosomes is minimized and by producing each generation, the algorithm tries to reach better solution than the previous one. As shown in Fig (8) comparing the effect of generation number.

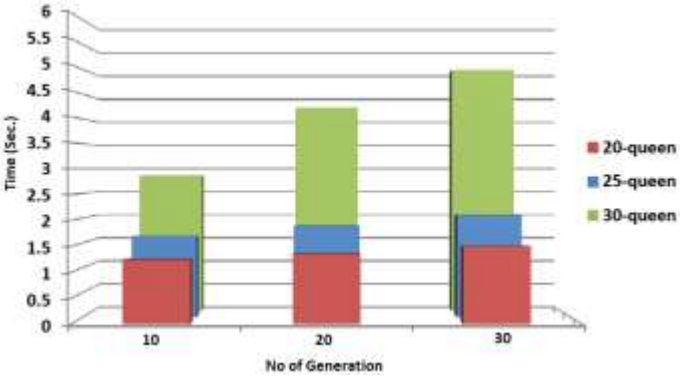

Fig (8): Comparing the Effect of Generation Number

6. Conclusion and Future Works

In this paper, we proposed an optimal solution for N-Queens problem using the combination of GA operators. In GA, the operators such as crossover and mutation had considerable effect on searching space of optimization problems. Combining crossover and operators provide the possibility for N-Queens problem to minimize the number of queen conflicts. The optimal solution is achieved in less computational time. And in the future, we hope to reach more optimal solution for N-Queens problem by combining other crossover methods in less computational time.

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Table (2): The Effect of the Number of Generation on Operation Time

Size N	No of Generation	Time (Sec.)
20	10	1.23
	20	**1.34**
	30	**1.49**
25	10	1.62
	20	**1.83**
	30	**2.05**
30	10	**2.85**
	20	**4.28**
	30	5.07

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