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DISCRETE PENGUINS SEARCH OPTIMIZATION ALGORITHM TO SOLVE THE TRAVELING SALESMAN PROBLEM

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ABSTRACT
The traveling salesman problem (TSP) is an NP-hard combinatorial optimization problem that can be solved by finding optimal solutions. In this work we present an adaptation of the metaheuristic "Penguins Search Optimization Algorithm" (PeSOA) depending on the Penguins hunting strategies. The results show that the proposed adaptation which is favorably compared with the methods proposed in the literature, gives very good results in a reasonable time.

Keywords: *Metaheuristic, Traveling Salesman Problem, PeSOA, Combinatorial Optimization.*

1. INTRODUCTION

The traveling salesman problem (TSP) ([1]) is one of the most ancient and extensively treated problems in the operational research. This problem can be formulated as follows: A commercial traveler should visit a number of cities; he must start and end his journey in the same city of departure but visiting each of the other cities only once. The objective is to find the tour that has the minimal total distance traveled.

The importance of this problem appears in many application areas such as telecommunications ([2]), transport and logistics ([3]).or in the industry ([4]).
Since the 19th century, the traveling salesman problem (TSP) has been ranked among the most difficult problems. But now we can resolve it with the heuristic appearance, for example, Local search ([5-6]), simulated annealing ([7-8]), and tabu search ([9-10]) and by the appearance of metaheuristic, Such as, genetic algorithm([11-13]), Ant Colony System ([14-15]),particle swarm optimization([16-18]),bee colony optimization([19-21]),cat swarm optimization([22]) and harmony search algorithm([23]). In this paper, we propose to solve this problem using the algorithm of PeSOA ([24]) .In this research, the first part will be devoted to the description of TSP, the second provides an overview of the algorithm of PeSOA, the third part is an adaptation of the algorithm of PeSOA or TSP, The fourth discusses the results of tests using instances of TSPLIB and finally a general conclusion.

2. THE TRAVELING SALESMAN PROBLEM (TSP).

The traveling salesman problem(TSP) is a classic optimization problem which was mentioned for the first time in 1930 by the Viennese mathematician Karl Menger, it's about finding the shortest way passing only once by a limited number of cities N, And returning to the starting point.

The traveling salesman problem (TSP) is composed of a set of variables:

C_{ij} : The distance between two cities i and j.

N: Number of cities

X_{ij} :Binary variable that takes the value 1 if the city i is visited immediately before the city j else, this variable takes the value 0.

The problem is to minimize the length of the Hamiltonian cycle. The objective function is:

$$\text{Minimize : } Z = \sum_{i=1}^{n}\sum_{j=1}^{n} C_{ij} X_{ij} \qquad (1)$$

The constraints are:

$$\sum_{j=1}^{n} x_{ij} = 1 \qquad i = 1,.....,n \qquad (2)$$

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$$\sum_{i=1}^{n} x_{ij} = 1 \qquad j = 1,.....,n \qquad (3)$$

$$\sum_{i \in S} \sum_{j \in S} x_{ij} \geq 1 \qquad s= 1,....,n \qquad (4)$$

$$x_{ij} \in \{0,1\} \qquad \forall i, \forall j$$

The constraints (2) and (3) allow to visit all cities exactly one and only once. The third constraint (4) prohibits solutions which will form sub-rounds; it is generally called removal sub-rounds constraint.

3. THE PESOA ALGORITHM.

PeSOA is a method for optimizing nonlinear systems developed by Youcef Gheraibia and Abdelouahab Moussaoui in 2013 to solve optimization problems ([21]), this is a simplified model of social relations, which is the hunting of the Penguins. The hunting strategy of the Penguins is a collaborative work of effort and timing, they benefit of their dives by optimizing the overall energy in the process of collective hunting and nutrition.

In the PeSOA algorithm each penguin is represented by its position and the number of fish consumed. The distribution of penguins is based on probabilities of existence of fish in a position. The penguins are divided into groups and begin research in random positions, after a fixed number of dives, penguins return to the ice and begin to share information such as position and the amount of nutrients found.

Penguins of one or more groups that have some food follow in the next dive penguins that chased a lot of fish. Each penguin that represents solution is distributed in groups, and each group searches for meals at a defined place. In this process the penguins out for the good of all groups and start searching in a specific environment based on the likelihood of food sectors, accordingly, in each cycle the position of the penguin with each new solution is adjusted as in the following equation:

$$\mathbf{D_{new} = D_{id} + rand\ () \mid X_{best} - X_{id} \mid (5).}$$

$\mathbf{D_{id}}$ is the last best solution accord for this penguin, **rand ()** is a random number of the distribution, and has three solutions, the best local solution ($\mathbf{X_{best}}$), the final solution ($\mathbf{X_{id}}$) and the new solution ($\mathbf{D_{new}}$).the calculations in equation (5) of the solution update are repeated for every penguin in each group, and after several dives, penguins communicate to each other the best solution represented by the number of fish consumed.

Algorithm (1) : pseudo code for basic PeSOA

•Generate random population of P solutions (penguins) in groups;
• Initialize the probability of existence of fish in the holes and levels;
While (iteration<number of generations) do
 For each individual $i \in P$ do
  While (oxygen reserves are not depleted) do
   - Take a random step.
   - Improve the penguin position using Eqs. (5)
   - Update quantities of fish eaten for this penguin.
  End while
 End for
 - Update quantities of eaten fish in the holes, levels and the best group.
 - Redistributes the probabilities of penguins in holes and levels.
 - Update best-solution:
End while.

4. ADAPTATION OF THE PENGUINS SEARCH OPTIMIZATION ALGORITHM TO SOLVING THE TRAVELLING SALESMAN PROBLEM.

To adapt the method PeSOA for the traveling salesman problem, with preservation of the philosophy of the method, it requires firstly to do a parameter adaptation of PeSOA with TSP and secondly rewrite the equation database system of PeSOA(equation (5)) to improve the position of the penguin to find optimal solutions, which makes the equation(5) as follows :

$$X_{new} = X_{id} \oplus rand\ () \otimes (X_{best} - X_{id})\ (6).$$

As:

Position: This is the solution represented by the Hamiltonian path.

$\mathbf{X_{new}}$: The new solution.

$\mathbf{X_{id}}$: The current solution.

$\mathbf{X_{best}}$: The best solution in the population.

4.1 Algebra of Pesoa

Before we start to define the operations, we define variables X and X ' as two positions / path of the salesman, and Q as a set of links (x,y) to perform all permutations that may be appointed : displacement .

Example: Q = $\{(x_1, y_1)\ (x_2, y_2)\ \dots\ (x_n, y_n)\}$ with $x_i \neq y_i$

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The addition $\oplus$:
This applies between one position and displacement and returns to a position. The result is obtained by successive permutations of the elements X taking into account those of Q. It is only used during the update of the position.
Example: X= {1 2 3 4 5 6} and Q = {(1, 2) (4, 5)}
X' = X $\oplus Q$ Return X'= {2 1 3 5 4 6}.

The multiplication $\otimes$:
This is done between a real k and displacement Q. Different cases are considered according to the real.

- If $k = 0$ then: $K \otimes Q = \Phi$.
- If $0 < k < 1$ then: $K \otimes Q = E(k \otimes |V|)$ where |V| is the number of elements V and E(x) is the entire upper part of x.
- If k> 1 then we separate integer from decimal where k = n + x whether n and x correspond respectively to the integer and the decimal parts of k. We thereby reduce each party to the previous cases.
- If k< 0 then : $K \otimes Q = |k| \otimes Q$ returns to the previous case of a value of |k|.

Example: k=0,5 and Q = {(1, 2) (4, 5)}
$K \otimes Q$ return Q = {(1, 2)}.

The subtraction - :
The subtraction is performed between two positions and returns a set of permutations that can go from the first to the second position.
Example: whether X1 = {1 2 3 4 5} and
X2 = {1 2 4 3 5} then Q=X1 - X2
Return Q= {(2, 3) (4, 5)}.

4.2 Algorithm PeSOA to solve TSP.

The following pseudo code describes how the algorithm PeSOA was applied to solve our problem TSP.

Algorithm (2) : pseudo code PeSOA for TSP

Initialize the population P.
Initialization of the parameters:

- Gene: number of generations.
- RO2: oxygen reserves.
- BestSol: best solution.

```
Calculate best individual of population BestGp
While (iteration<gene) do
  For each individual do
    While (RO2>0) do
      Calculate new solutions xi using equation (6).
      Choose the best solutions of xi.
    End while
  End for
//Update BestGp and BestSol
  If (f (xid) < f (BestGp)) Then
    BestGp=xid.
  End If
  If (f (BestGp) <f(BestSol)) Then
    BestSol = BestGp;
  End If
End while.
```

- ✓ Number of generations (Gene): number of iterations needed to find the optimal solution.
- ✓ The population (P): a set of solutions to the problem. The size of the initial population is left to the programmer, it should be between 80 and 100 individuals and will often be ample, both for the quality of the solutions and for the running time of our algorithm.
- ✓ The variable oxygen supply (RO2): an integer shows the number of updating a solution by using the equation (6), its value must be greater than 0. The best value for this variable is 5(figure 1).

5. EXPERIMENTAL RESULTS.

The implementation of the algorithm PeSOA in C and the run on multiple instances of TSP using a pc with Intel (R) Core (TM) 2 Duo CPU 2.00GHz M370@2.40GHZ 2.40GHZ and 4,00 Go of RAM. Each instance runs 10 times.
The first feature of our program is to read the TSP files and calculate distances between cities then storing these data in a distance matrix. The time of these operations is not included in the execution time of our algorithm. Therefore our program generates a random population of initial solutions. There are three keys parameters that influenced on the results of the performance of our algorithm: the size of the population (NP), generation number (gene) and reserve oxygen (RO2).The parameter values are obtained after completing 10 experiments on each variable in order to find the best value for a very good running time of our algorithm .the following table shows the best values found and used for these parameters:

Table 1: Value Of Uses Parameters

Parameter	Value
RO2	5
Gene	800000
NP	80

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The figure below illustrates the supply of oxygen with time of PeSOA algorithm for instance, the TSPLIB library Berlin52 and Att48. This figure shows that when we increase the value RO2 the time increases.

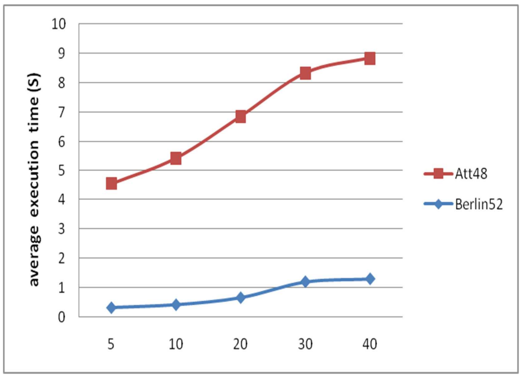

Figure1: The Relationship between the Average Execution Time and the value of RO2.

Table 2 presents the numerical results. Where the first column contains the name of the proceeding (Instance), the second shows the number of node (Nbr node), the third shows the best result found by the documentation TSPLIB (Optimum), the fourth presents the best result (BestR) obtained by the application of the algorithm PeSOA, the fifth contains the worst results (WorstR), the sixth the percentage error (Err) and the last one is the average execution time (Tps).

$$\mathbf{Err} = \frac{\frac{BestR + \mathrm{WorstR}}{2} - \mathrm{Optimum}}{\mathrm{Optimum}}$$

Table 2: Numericals Results Obtained

Instance	Nbr node	Optimum	BestR	WorstR	Err(%)	Tps(s)
att48	48	33522	33522	33522	0	4,07
berlin52	52	7542	7542	7542	0	0,42
bier127	127	118282	118282	119693	0,59	550,28
eil51	51	426	426	427	0,11	2,5
eil76	76	538	538	538	0	24,42
eil101	101	629	629	630	0.07	209,54
ch130	130	6110	6110	6172	0.50	928,16
ch150	150	6528	6528	6573	0,34	1968
pr76	76	108159	108159	108159	0	20,63
pr107	107	44303	44303	44387	0.09	232,96
pr144	144	58537	58537	58537	0	130,78
pr124	124	59030	59030	59030	0	153,92
kroa100	100	21282	21282	21282	0	114,04
krob100	100	22141	22141	22199	0.13	113,46
kroc100	100	20749	20749	21010	0.62	75,9
krod100	100	21294	21294	21389	0.22	581,05
kroe100	100	22068	22068	22106	0,08	311,39
rat99	99	1211	1211	1211	0	322,9
st70	70	675	675	675	0	13,26
lin105	105	14379	14379	14379	0	74.38
u159	159	42080	42080	42396	0, 3	564,95
dantzig42	42	699	699	699	0	0,72
rd100	100	7910	7910	7910	0	190,41
swiss42	42	1273	1273	1273	0	16,43
ulysses16	16	6859	6859	6859	0	73
ulysses22	22	7013	7013	7013	0	95

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burma14	14	3323	3323	3323	0	0 ,02
a280	280	2579	2579	2652	1,4	10006,16
pr 152	152	73682	73682	73818	0,09	725,23
d198	198	15780	15780	15793	0,04	5638,4
ts225	225	126643	126643	126643	0	2455,88
fl417	417	11861	11881	12524	2,87	8869,12
gil262	262	2378	2388	2416	1	2174,79

After applying the results of our algorithm on a set of instances of the problem contained in the above table we compare the performance of our algorithm to other existing algorithms: Simulated annealing (SA) Genetic Algorithm (GA), ant colony system (ACS), particle swarm optimization (PSO), Bee colony optimization, Cat swarm optimization CSO) and Harmony search algorithm (HS).

Table 3: Results Obtained By Different Metaheuristics

Method	Instance (optimal solution)				
	Pr76 (108159)	Eil51 (426)	St70 (675)	Eil76 (538)	KroA100 (21282)
PeSOA	108159	426	675	538	21282
SA([8])	109769	---	678	---	21343
GA ([13])	117979.83	432	---	565,97	27119.64
ACS([15])	---	434.178	---	559.7041	21684.64
PSO([18])	108280	427	675	546	---
BCO([21])	---	428	---	539	21762
CSO([22])	---	426	675	538	21282
HS([23])	108159	426.3	675	560.4	21282

6. CONCLUSION:

This paper has proposed an adaptation of Penguins Search Optimization algorithm to solve a combinatorial optimization problem, by redefining operators and operations. The performances of this method were proved in the experimental results applying PeSOA algorithm to solve some instances of TSP problem. The results were compared with the best optimal solutions found by other methods such as SA, HS, GA, ACO, BCO, PSO, and CSO. Future research should focus on applying the presented method to solve other real applications based on the traveling salesman problem.

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