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Improvement Initial Solution Water Flow Like Algorithm Using Simulated Annealing for Travelling Salesman Problem

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ABSTRACT

The water flow like algorithm (WFA) is a relatively new metaheuristic algorithm, which has shown good solution for the travelling salesman problem (TSP) and is comparable to state of the art results. There are various factor influence the performance of WFA for TSP. However, initial solution has also influence the performance of the algorithm. The basic of WFA uses a random searching method for initialization technique. Previous WFA-TSP used nearest neighbor for initial solution. Therefore this paper presents the performance of use simulated annealing (SA) in initial solution for WFA-TSP. The algorithms are evaluated using 16 benchmarks TSP datasets. The experimental results show that the proposed SA-WFA-TSP outperforms due to its capacity of reduce computing time compared with others algorithms especially for large dataset. Therefore, it can be concluded that SA-WFA-TSP has become the state of the art algorithm for TSP.

Keywords: Nature-inspired Metaheuristics, Water Flow Liked Algorithm, Simulated Annealing Algorithm, Combinatorial Optimization, Traveling Salesman Problem
JEL Classifications: C22, C61

1. INTRODUCTION

The travelling salesman problem (TSP) is one of the most widely studied problems in combinatorial optimization (CO) (Martin and Otto, 1996). The TSP aims to find the shortest trip from a starting point, visiting all cities in a route exactly once and returning to the start point. The total number of possible routes is (n−1)!/2 for n number of cities. For example, if the TSP is applied on a large dataset with thousands of cities, the number of possible solutions is huge (2.01e+2567 for 1000 cities).

The water flow like algorithm (WFA) is a dynamic-based solution to solve object grouping problems from the start (Yang and Wang, 2007). The number of solution agents deployed dynamically changes throughout the water flow, splitting and merging. Applied the WFA to solve the TSP and demonstrated that the solution outperformed the ant colony optimization (ACO) in terms of solution quality and computation time (Srour et al., 2014).

Initial solution is important part in the process of algorithm by affected the result. This research aims to improve initial solution WFA by using simulated annealing (SA) compare with Ayman et al. that using nearest neighbors (NN) as initialization technique. SA is one of the most effective methods for improving the effective algorithm in helping optimization in term of time quality (Bank et al., 2012). The performance of the algorithms will be compared in terms of solution quality and computation time.

This paper will be organized as follows: Section 2 presents the proposed WFA using SA for initialization solution in TSP, Section 3 discusses the experiment setups, followed by the experiment results divided into solution quality, computation time and proposed algorithm behavior discussion. The last section concludes with the results and future works.

2. RELATED WORKS

Metaheuristic is an approach that produces efficient, near-optimal solutions without any guarantee of finding the global optimal or even bounded solution (Talbi, 2009). A metaheuristic algorithm aims for a balance between diversification (exploration) and intensification (exploitation). The term diversification refers to exploring a larger search space. Intensification refers to the exploitation of the accumulated search experience (Talbi, 2009). The most popular classification is known as the single solution based metaheuristic and population based metaheuristic solution (Talbi, 2009). A single solution based metaheuristic, such as SA (Kirkpatrick et al., 1983) and Tabu search works on improving based on a single solution agent (Glover, 1989); it is easy to implement but lacks exploration and easily stagnates at the local optima, whilst the population based metaheuristic performs searches with multiple initial starting points in parallel, such as the ACO (Dorigo and Gambardella, 1997) and genetic algorithm (GA) (Goldberg, 1989). However, it suffers from a quick convergence and unavoidable redundant searches, and uses much memory during a search (Talbi, 2009).

A novel metaheuristic algorithm proposed by Yang and Wang (2007) known as the WFA has shown an ability of balancing between exploration and exploitation, due to the idea of dynamic population searching agents. The WFA has been successfully adapted and applied in different CO problems including bin-packing (Yang and Wang, 2007), manufacturing cell formation problems (Wu et al., 2010), and nurse scheduling (Shahrezaei et al., 2011). The WFA for solving the TSP is shown to outperform the state of the art metaheuristics in this paper (Srour et al., 2014).

The basic operations of the WFA for solving the TSP include initialization, flow splitting and moving, flow merging, water evaporation, and water precipitation (Srour et al., 2014).

Initialization includes parameter setting and initial solution generation. The original WFA is adopted for the parameter setting (Yang and Wang, 2007). The initial solution is generated by the NN. Normally, the process of enhancement of the WFA only starts after the initialization process.

The flow splitting operation is conducted and depends on the flow momentum value. After that, the moving operation is conducted where the design is based on the type of target problem being solved. The algorithm for the flow moving process combines two types of neighborhood structures, namely the insertion move and k-opt.

The flow merging operation is the operation that combines more than two flow moves to the same location. This operation merges more than one flow into a single flow. Masses and momentums accumulate to compose an integrated flow to reinforce the solution search. This accumulation helps the stagnant flow to escape from the trapped location. This operation checks a flow with others whether they share the same location, and if it does, the latter flow will merge into the former one. The merging operation is executed to eliminate redundant flows.

The water evaporation operation is performed after the flow merging operation. This operation aims to simulate the natural evaporation of water into the air. Water evaporation is executed when evaporation conditions are met. The WFA uses the concept of water evaporation for preparing regeneration flows to increase the wideness of a solution search.

When the evaporated water accumulates to a certain amount, it will return to the ground. This process is known as the precipitation operation, and it is the natural rainfall behavior. This operation achieves redistribution of flows that escape from the local optima and spread the solution search range. Two types of precipitation are used in the WFA known as the enforced precipitation and regular precipitation.

The initial stage is one stage where we can help in achieving the optimization and increase the speed of computing time and simplify data set for early stage before further processing takes place. Initialization is also an early solution to the first flow that can be built by using random or heuristic contraction. This is because the initialization must be configured and initiated before the start of the optimization process. The good algorithm for initialization technique is the algorithm that can optimize more efficient and reliable and can include single solution based metaheuristics.

Single solution based metaheuristic can solve optimization problem with one solution known as the trajectory through the searching area by interactive process that makes the movement of current solutions on the best solutions. The structure of the neighborhood is a common searching concept to all single metaheuristic (Talbi, 2009). SA was used in initialization technique in WFA for solving TSP problem.

Searching for algorithm is applied from this annealing process with initial solution and then continues with several iterations. At each iteration, the solution for local search generated, if new solution is better than current solutions, improvement neighbor solution would be acceptable, if not, the new solution will be accepted but depends on two criteria. The first criteria are the difference neighbor solutions during the construction of a new neighborhood. The second is the value at the current temperature. If the temperature is still high, the neighbor solution will be accepted habitually. However, the solution neighbor had to go through probability calculations value to determine the neighbor solution acceptable or not as shown in this expression P = Exp ((current distance – new distance)/temperature).

SA has been applied in CO problems such as scheduling problem (Zhang and Wu, 2010). According Hosam and Ashraf (2015) the result of the study show that SA algorithm takes less time to find solution to the problem of scheduling. This shows the SA algorithm is one of the most effective in helping to optimize the time taken in solving a problem. Supported by Hosam and Ashraf (2015) which stated SA comes in the first order in time execution (<1 s) and gives average shortest distance results between GA and ACO. It showed that SA algorithm one of the algorithms that is very effective in helping to optimize the time taken to solve a problem. Initialization technique of SA designed respectively.

3. PROPOSED WFA USING K-OPT FOR TSP

The WFA for the TSP consists of five basic operations mentioned in the previous section, and nine equations and 11 steps described by the proposed WFA. This section proposed the WFA for the TSP using SA for initialization technique with 2-opt based on (Srour et al., 2014). Figure 1 shows the proposed WFA for the TSP using SA with 2-opt, respectively.

Firstly, this operation starts with the initialization, where the initial solution is generated by using the proposed algorithm that is SA (line 2 and 3). The process of enhancement of the WFA only starts after the initialization process.

Next, the process continues on to the flow splitting and moving operation (line 5 to 11). The flow splitting operation is conducted and depends on the flow momentum value. The moving operation is conducted where the design is based on the type of target problem being solved. The algorithm for the flow moving process combines two types of neighborhood structures, namely the insertion move and k-opt. The insertion move is used to determine the new locations of the sub-flows to find the best neighbor solution for each sub-flow.

The flow merging operation (line 12) is the operation that combines more than two flow moves that share the same location to the same location. The water evaporation (line 14) operation is performed after the flow merging operation. This operation aims to simulate the natural evaporation of water into the air. After the evaporated water accumulates to a certain amount, it will return to the ground. This process is known as the precipitation operation (line 15 to 18), and it is a natural rainfall behavior.

4. EXPERIMENTS SETUP

The performance of the proposed WFA-TSP using SA as initialization technique and re-run the same coding with WFA-TSP are evaluated by conducting 16 TSP benchmark datasets from TSPLIB ranging from 51 to 3795, which represent small, medium, and large sized datasets (Srour et al., 2014). Therefore, WFA-TSP solution results may a little bit difference between the results in Ayman published paper (Srour et al., 2014). All algorithms are implemented in a Java environment JDK 1.6. Each dataset is based on 10 independent operations with 10,000 iterations used to obtain the statistical test results.

Figure 1: Pseudo-code of simulated annealing in initialization technique

```
Simulated annealing ()
{
    Scurrent = solution.clone();
    localbestTour=solution.clone();
       {
          Heating++;
          WHILE (counter < iteration) {
             {
IF (SAlocalSearch)
2-opt get value;
currentIteration++;
IF (solution length < current length) {
Current length = solution length;
IF (solution length < best length) {
Best length = solution length;
}
} ELSE IF (solution length > current length) {
Calculate the worst solution;
}
Temperature *= cool rate
                                          }
    }
}
```

The experiment was conducted using an Intel Pentium i3 2.4 GHz processor and 4GB RAM. The setting of the parameters for the algorithm testing was adopted from where the base momentum is 20, initial mass is 8, initial velocity is 5 and sub flow number limit is 3 (Srour et al., 2014).

A statistical descriptive analysis is used to obtain the mean, standard deviation, best solution, average computation time, average iteration number, percentage deviation of the average with the best-known solution of the tested algorithms, and based on the values of the mean in terms of solution quality and computation time, the improvement percentage could be calculated.

5. EXPERIMENTS RESULTS

The results are analyzed in two types of measurements: Solution quality and computation time taken to get the best solution.

Figure 2 show that the differences of average in computing time by using the difference initialization technique. SA-WFA-TSP indicate optimum performance in terms of solution quality for 1 dataset (kroA100) from a total of 16 datasets and PDavg = 0 (The percentage of deviation of the mean values regarding the best-known solution). However, SA-WFA-TSP give better results in terms of computing time average for all datasets compared with NN-WFA-TSP showed an incensement ranging of percentage from 5.263% to 3388.52% as shown in Figure 2. This indicates a reduction in computing time especially on large dataset (Talbi, 2009). Five datasets (kroA100, ch15, rat575, D1655, f13795) which has reduced the value of standard deviation of NN-WFA-TSP.

Table 1 proves that the average of computing time that have been generated form WFA using SA as initialization technique can affect the time, especially when dealing with large- size problems. Calculating time computing average for various algorithms has changed a lot including datasets f13795 and fl1400 as shown in Figure 3.

The best of local average for SA has been calculated based on 10 independent iteration of each data as shown in Table 1. Best local an analysis of initialization technique that was used before it was taken as main input for running WFA.

6. CONCLUSION

This paper demonstrates the behavior and the function of initialization part in WFA and it shown that the propose of ability to speed up the process to reach solution in three different size of

Figure 3: Comparison of average computation time of the simulated annealing-water flow like algorithm (WFA)-travelling salesman problem (TSP), nearest neighbors-WFA-TSP for small, medium and large datasets

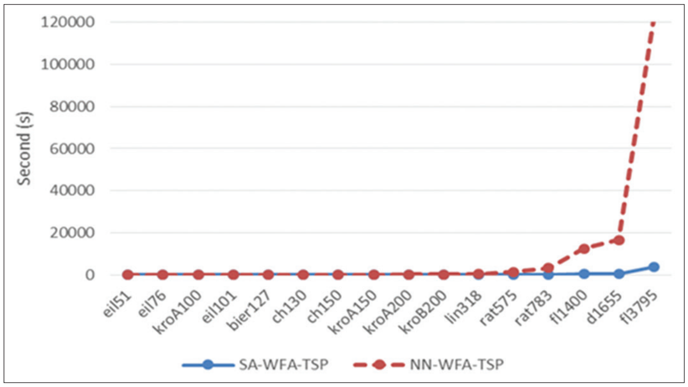

Figure 2: Pseudo-code of proposed water flow like algorithm for travelling salesman problem with simulated annealing respective

```
WFA_Algorithm ()
Generate an initial solution using SA (simulated
annealing)
WHILE (stop criterion is false) {
Cal. no. of sub-flows; //refer equation 1 in [12]
 Assign sub-flows new locations using insertion move 7   for each
 sub-flow //refer step 3 in [12]
k-opt =2
Find best neighbor using 2-opt //based on [12]
Distribute mass of flow to its sub-flows; //refer 13 equation 2 and
3 in [12]
Calculate the improvement in objective function;
Flow merging. //refer step 6 in [12]
Water evaporation. //refer step 7 in [12]
IF (rainfall required) {
Precipitation. //refer step 8 and step 9 in [12]
Flow Merging. //refer step 6 in [12]
}
IF (new best solution found)
Update best solution record.
}
```

dataset for TSP improved. Furthermore, the initialization technique in WFA also affects the accuracy of some dataset. Computing time is much depending on initialization technique in the algorithm. Therefore, it can be concluded that initialization technique in WFA has potential for more improvement using a more metaheuristics algorithm, such as ACO or GA.

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